metal treatment and Drop Forging

Vol. 25 : No. 150 MARCH, 1958 Price 2/6

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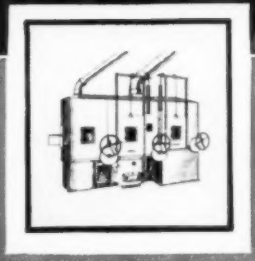

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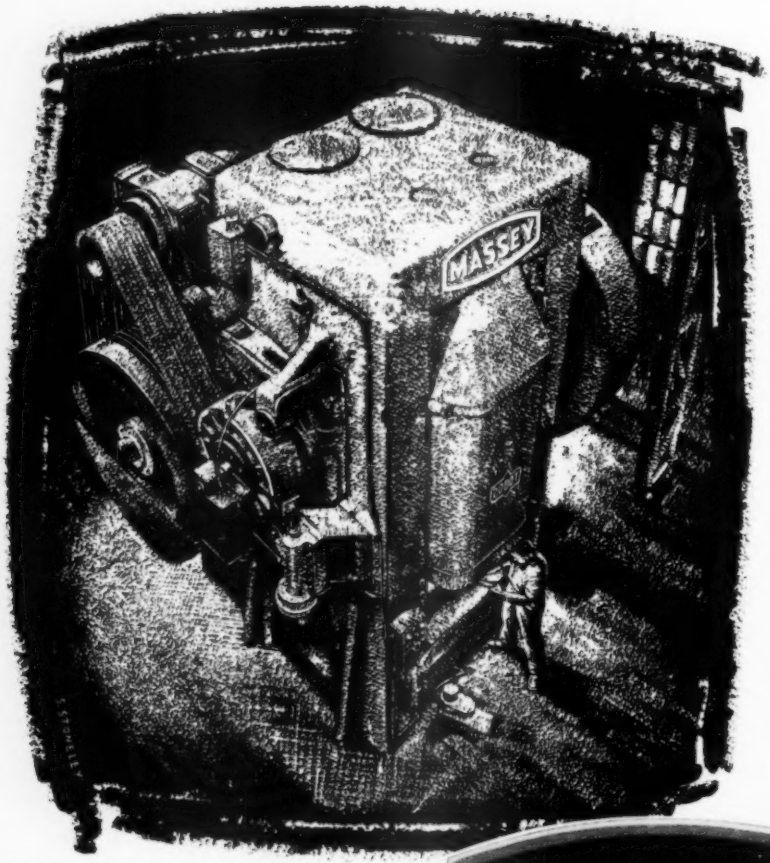

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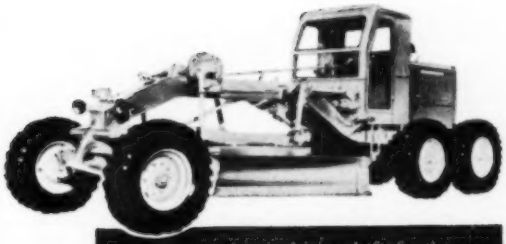

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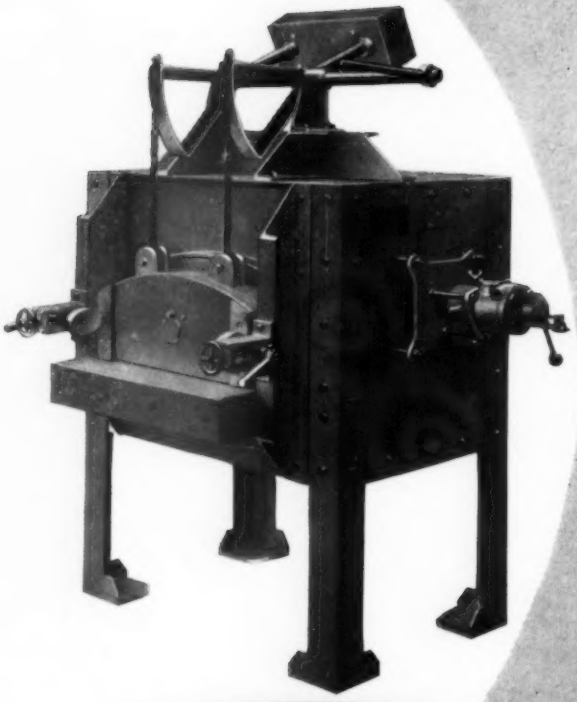

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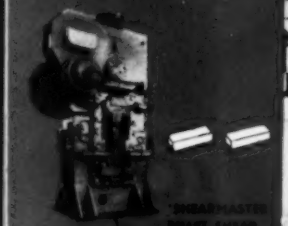

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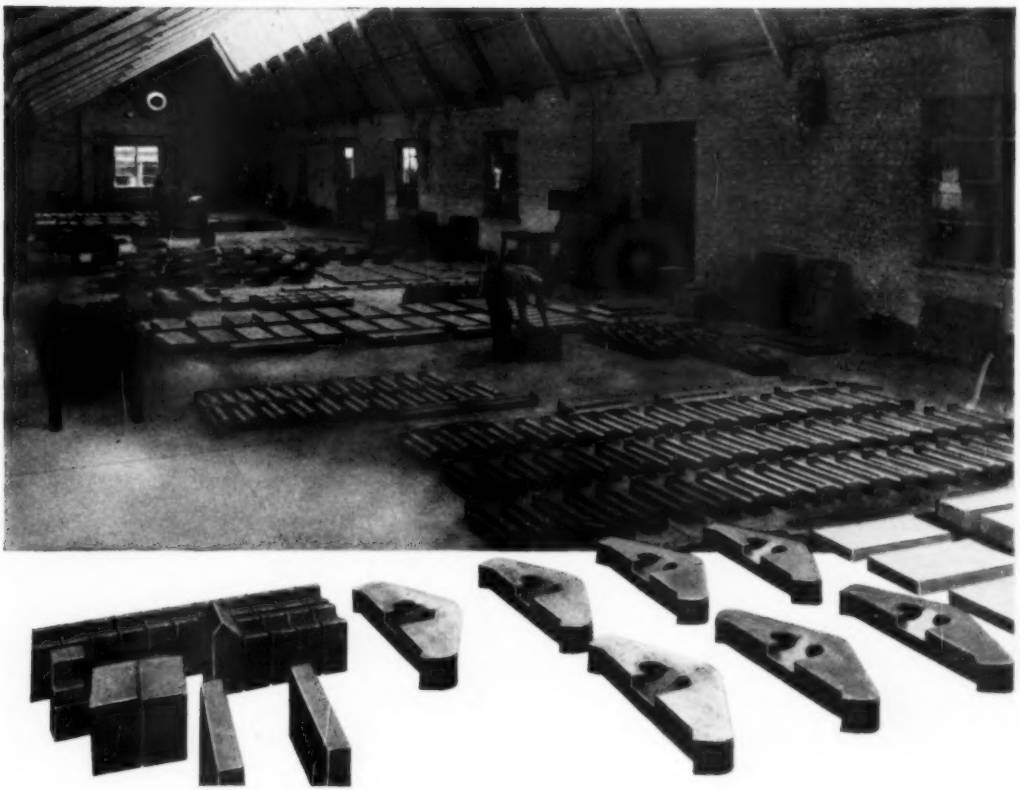

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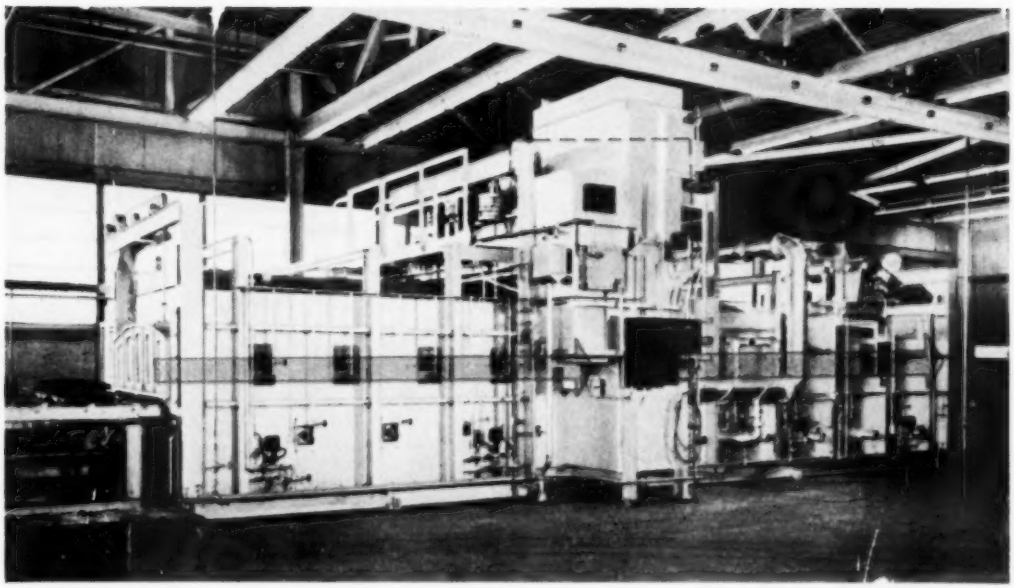

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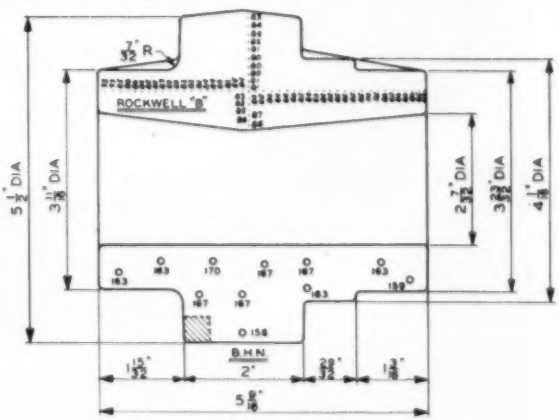

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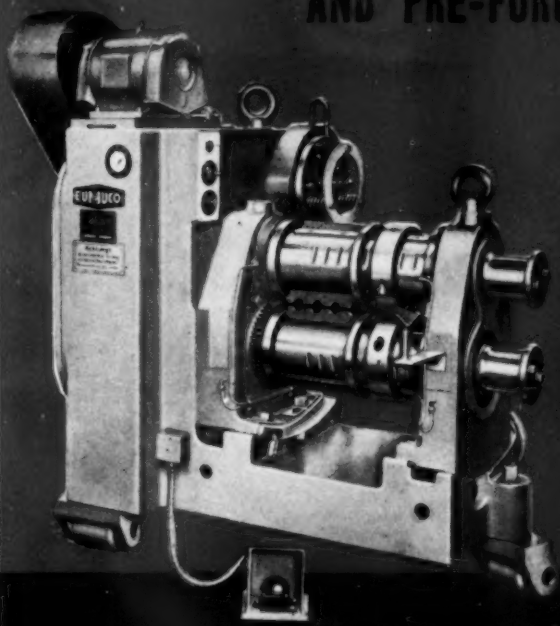

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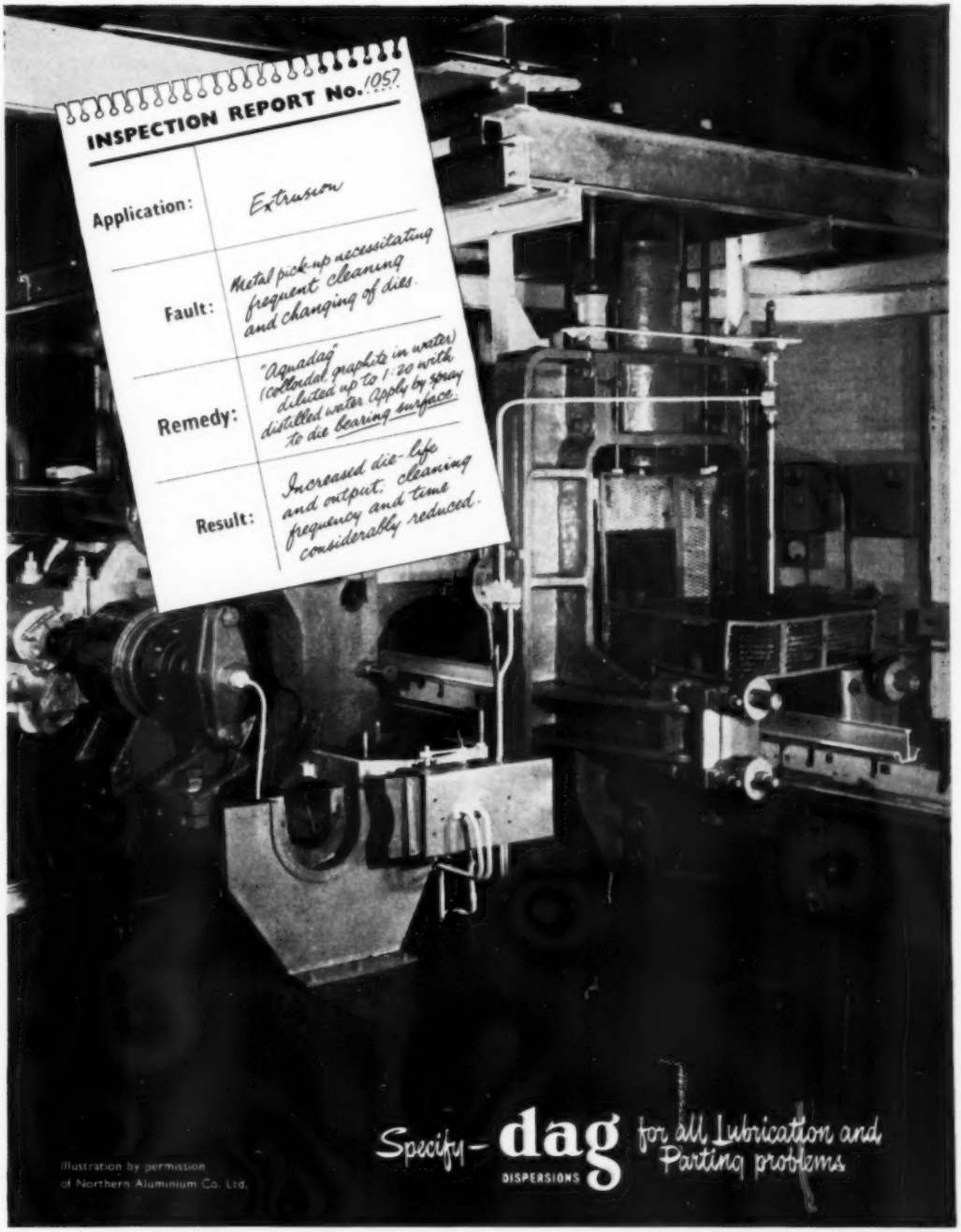
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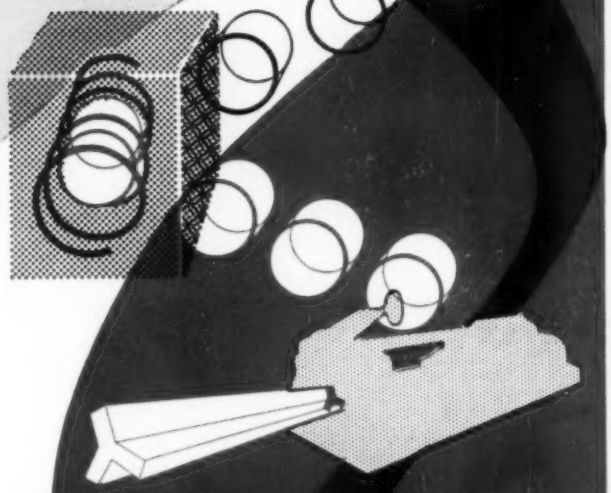

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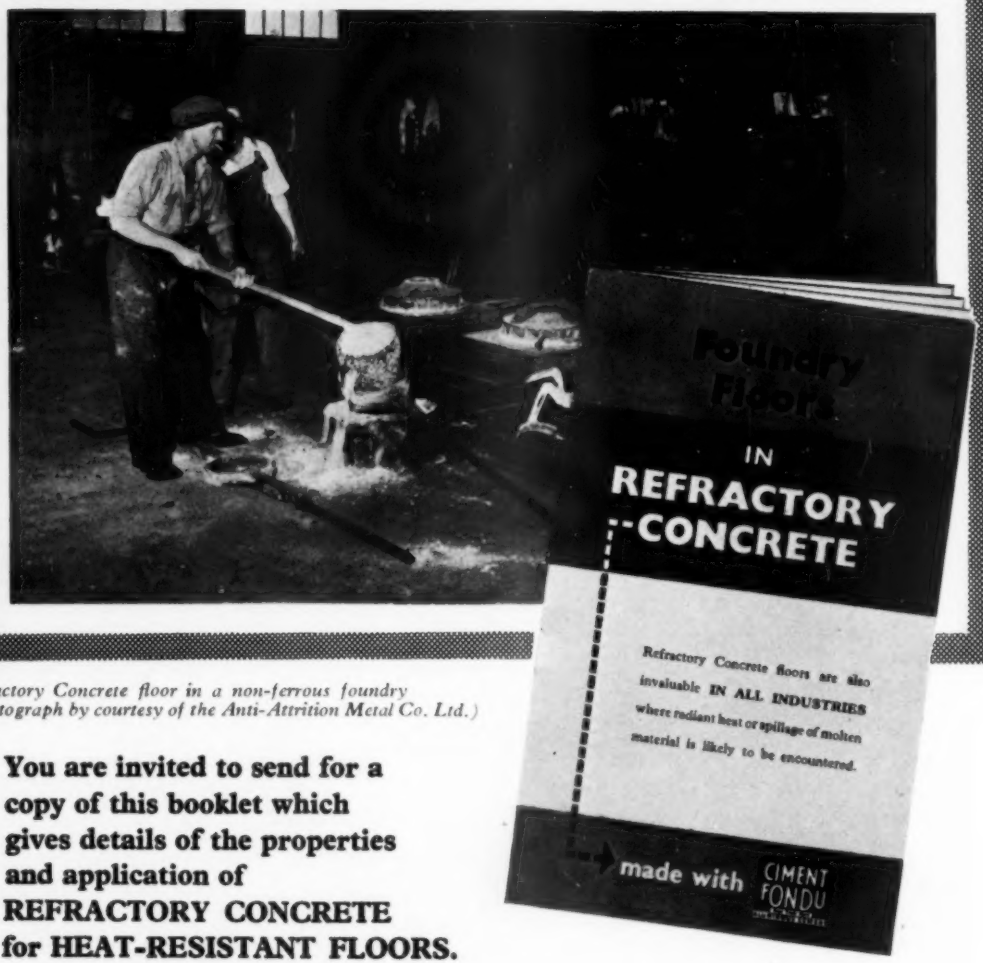
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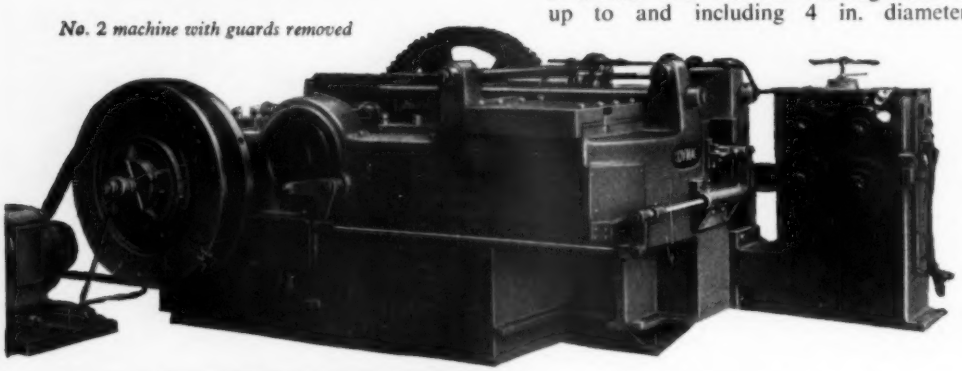

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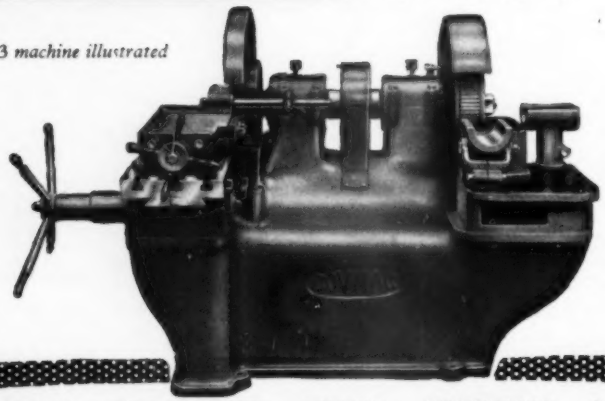

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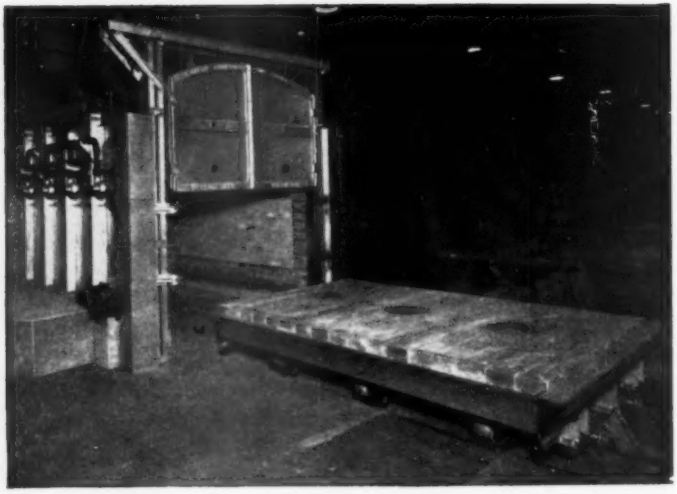

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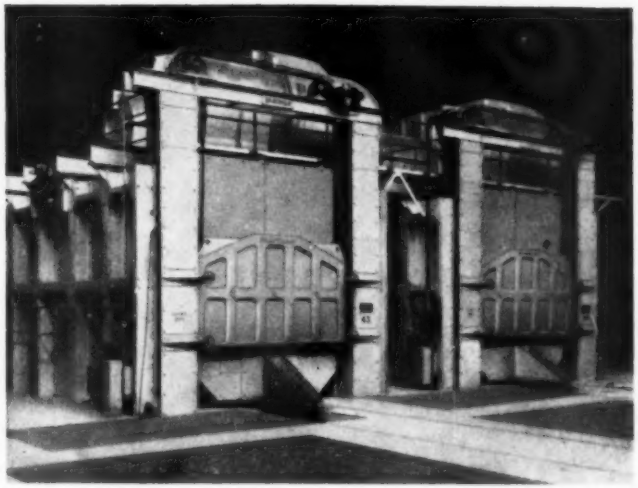

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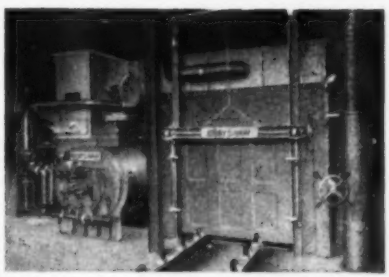

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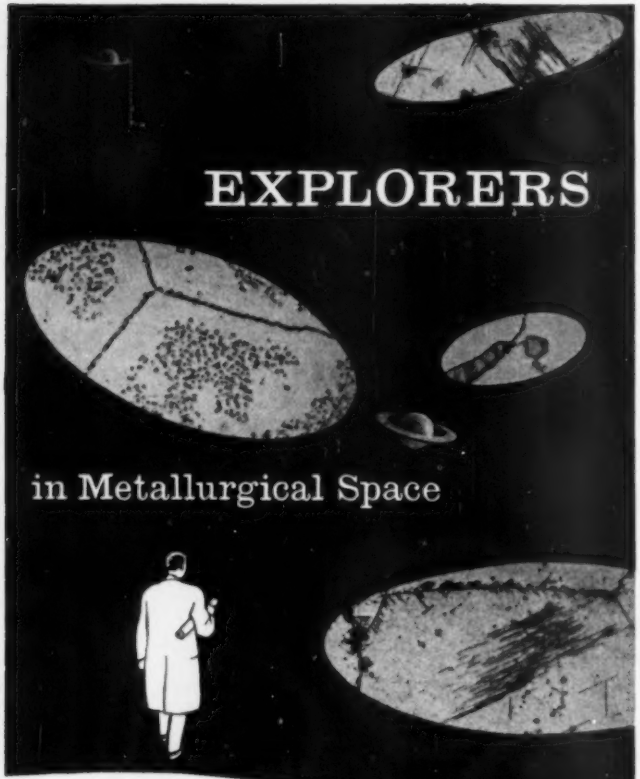

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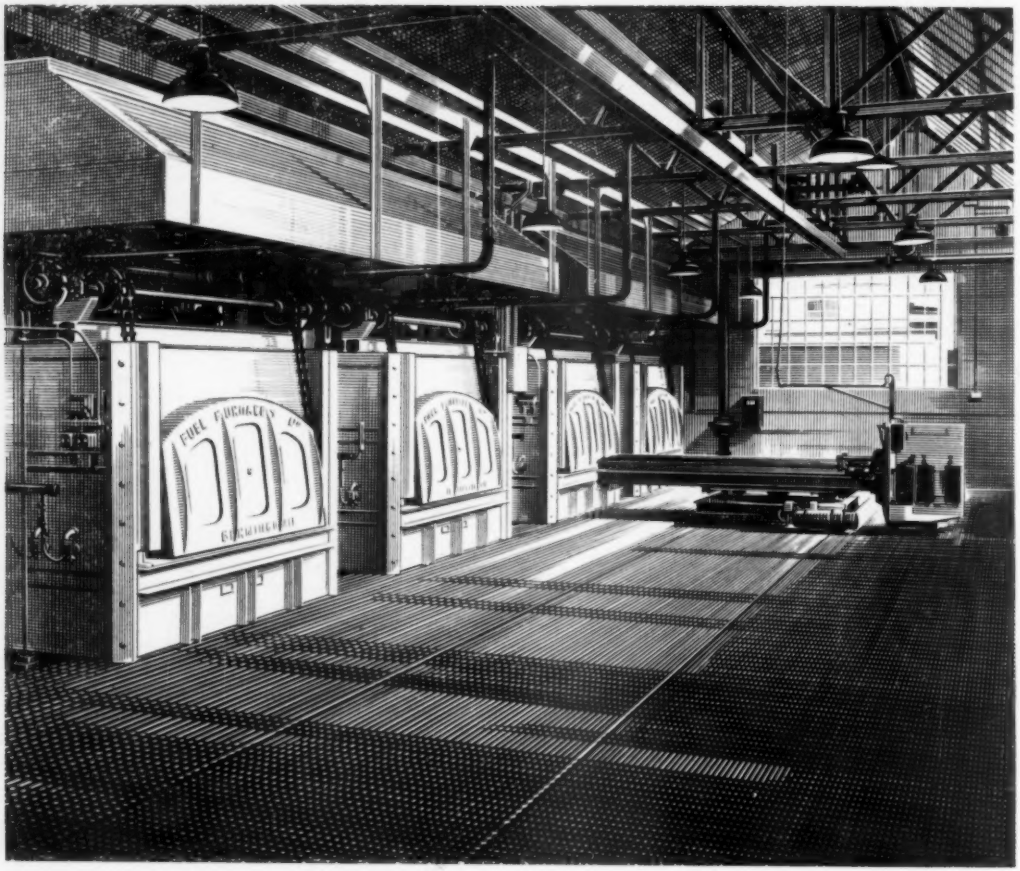

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Why Not Now?

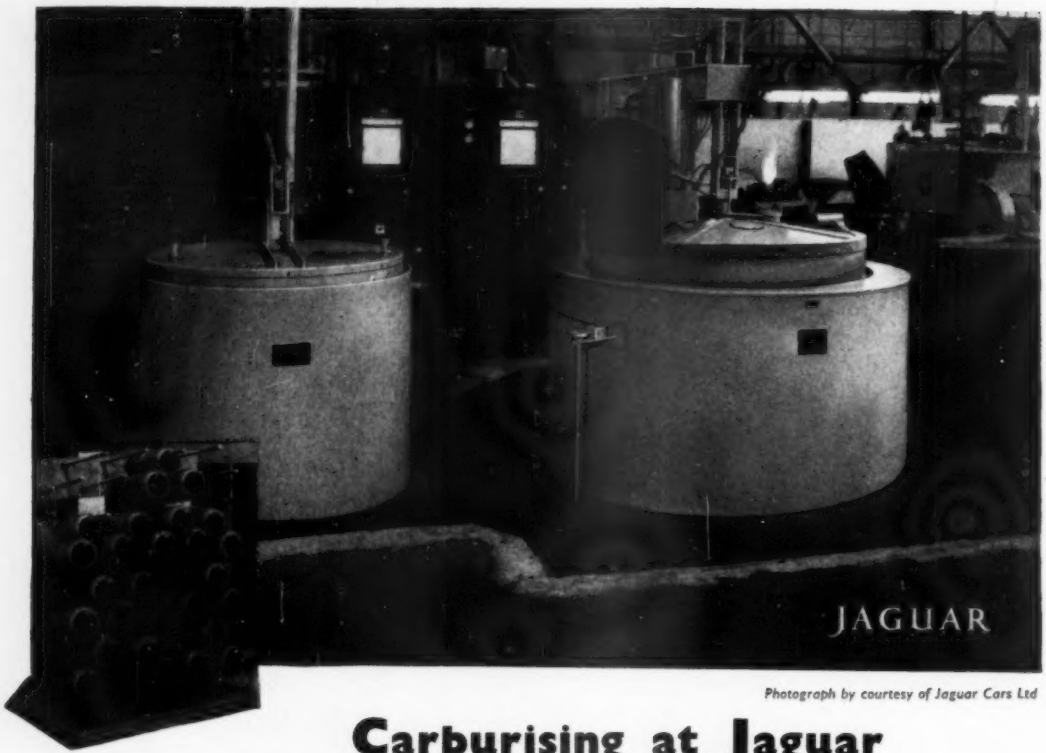
IN the course of his erudite, entertaining and admirably delivered inaugural lecture given on February 18, 1958, Professor F. D. Richardson, who occupies the Chair of Extraction Metallurgy at the Royal School of Mines (London), drew a diagram on the blackboard. On the basis of time, marked in years, a curve labelled 'The Art of Metallurgy' was shown descending, while a similar curve labelled 'The Science of Metallurgy' was shown ascending. At a point on the time-scale where the latter curve more or less reached its upper asymptote Professor Richardson made a mark and said that, in his view, this represented the moment (it appeared to be some five or ten years hence) when leading articles entitled 'Physical Chemistry Does It Again!' would be appearing in *Metal Treatment* and *Iron and Coal Trades Review*.

The roar of appreciation which greeted this sally left us in no doubt that most of the audience knew exactly what the lecturer meant—that in a few years' time, contrary to the opinion expressed frequently in these pages, physical chemistry would be so far advanced that it would be regularly leading to productive developments in the metallurgical field. Instead of expressing grave doubts as to the value of extended physico-chemical research the editor of this journal would be 'eating his words' and offering his congratulations to the new inventors whose developments would be the fruit of their extensive knowledge and understanding of physical chemistry.

Now when any of our statements are conclusively proved wrong we shall have no objection to making a hearty meal of them; but surely Professor Richardson does not need to wait for an unspecified number of years to show us the error of our ways! The present era of (in our view) exaggerated respect for physical chemistry dates roughly from 1944, when Professor H. J. T. Ellingham published his paper on the 'Thermodynamics of Oxides and Sulphides,' which was a brilliantly clear exposition of an exceedingly complex subject. For some 14 years, therefore, research has been going on in this field, and presumably more and more valuable data have been collected, all contributing to the healthy rise in the aforementioned 'Science of Metallurgy' curve. The same period has also been one of spectacular advances in the fields of practical extractive and refining techniques, some examples of which we have recently mentioned. There are probably many more, well known to Professor Richardson.

Now, for reasons which have been from time to time argued in these pages, we do not believe that physico-chemical research has ever been, or is ever likely to be, a fruitful source of process development. Examples we have quoted recently indicate that certain developments have taken place, not because of physical chemistry, but in spite of it. But Professor Richardson apparently expects us to believe that this is only because physical chemistry has not yet become sufficiently perfect; that we have only to wait a few more years for the physical chemists to 'catch up' with metallurgical knowledge. In our view such an idea is wholly mistaken. If 14 years are insufficient to allow this to come to pass, then we do not believe it will ever come to pass, even in a hundred years. Conversely, if we are wrong, and eventually physical chemistry does lead metallurgical development, then surely after 14 years there should be enough evidence to show that this is beginning to happen now.

We consider that a proper discussion of these questions should take place, not simply as an interesting exercise in scoring debating points, but as a matter of urgent national importance. The future industrial prosperity of this country depends to a large extent on the quality of technological graduates turned out by establishments such as the Royal School of Mines, and it is essential that these young men are not only given a sound



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Forgings and Machinability

G. H. JACKSON, F.I.M.

At the 1957 Technical Convention of the N.A.D.F.S., F. Corry, A.M.C.T., F.I.M., A.I.Prod.E., of Peter Wood & Co., Sheffield, in his address, 'Some factors affecting the machinability of forgings,' traced through in some detail the main processes giving rise to those features which could be objectionable to the user of the forging. This has prompted the author to call attention to others and to emphasize the inter-relation of some of those factors. Particular instances to illustrate more specifically the sources of difficulty faced by the production engineer are intended to bring home the necessity for each to play his part in maintaining maximum consistency. Mr. Jackson is technical officer of the National Association of Drop Forgers and Stampers

'MACHINABILITY' is a coined word, not yet to be found in the dictionary. It is, as yet, incapable of precise definition and still more impossible to write into a specification. In fact, its meaning is not always clear in production engineering, as is shown by the several conditions often embraced by this term. 'Machinability' has been used to cover the speed at which bar or forgings can be turned; the variation of machine tooling under normal conditions; the inability to maintain dimensional accuracy or tolerances; the necessity of alteration to machine tool setting; the loss of operator earnings and many other such nebulous headings.

It is, however, becoming an increasingly important subject to metal-user industries and is a worthy subject for research. Consequently, it is currently being investigated from several aspects. Theoretical approaches are difficult, but are being attempted and, if variations in machinability can eventually be shown by such an approach, to be associated with a property, composition or condition, then practical specification may be possible and acceptable. It must not be overlooked that in many cases there are two directly opposing interests involved, namely, the design requirements of the final product, and the production engineer's desire —sometimes almost a mania—to produce more quickly and therefore more cheaply, whether or not it does the job when made. Admittedly, there are large numbers of mere shapes which demand high-speed production.

If the more usual meaning of 'machinability' is taken as the speed at which a cutting operation can be carried out, then the subject can be sub-divided, firstly into improvements to make higher cutting speeds possible, and secondly, to control any known variables causing inconsistencies in the production cycles. The drop forger is not expected to contribute to the former, the responsibility of which is divided between the steelmaker and the machine-tool industry, but he is expected to control any factor arising from his processing known to influence machinability.

Measurement of Machinability

Many workers have endeavoured to measure machinability either as a numerical value of some variable, or by direct comparison. It is worth mentioning some of the more down-to-earth methods that have been tried. Perhaps more work has been carried out on dynamometer lathes or similar equipment, having as their object the measurement of power absorbed under cutting conditions, than any other type of equipment. Standardization of such equipments is made difficult by many other variables which cause too much inconsistency in results obtained. Such factors as standards of lubrication, accuracy of the cutting tools and adequate chip and swarf removal tend to swamp the sometimes relatively small differences in the material under test.

A further method is based on the absorption of energy in taking a single cut with a standard tool, in an equipment not unlike the Izod impact tester, but again, even very slight variations in tool dimensions produce too much variation in the results obtained to give any absolute values. A more practical approach intended to give comparative results, is to present a standard tool to the material under test at considerably higher cutting speeds and feeds that would be practical in pro-

technical training, but are also taught to think clearly regarding the role which science plays in industry, even if some of the conclusions cut across certain preconceived notions. Rather more than a year ago, on January 10, 1957, Mr. R. Peddie, of United Steel Companies, startled everybody by some pretty blunt remarks about the quality of present-day graduates—' no originality—little enterprise—limited ambition—in fact, very dull.' At the time we considered this statement a bit drastic and sweeping and not altogether fair, but we cannot now help feeling that if present-day students are being brought up to accept this kind of ' pie in the sky ' philosophy about physical chemistry then Mr. Peddie's strictures may well be justified.

The pages of *Metal Treatment* are open to everybody—we invite Professor Richardson to state his case, not five or ten years hence, but now.

Automatic Equipment

NOT only has automation come to stay, but, according to a Board of Trade inquiry carried out between the end of 1956 and April, 1957, a big increase in its use in industry and commerce is likely to take place in the next four or five years. By 1963 it would appear that digital computers will have become commonplace in the establishments of the major employers of clerical labour. Many companies are, or are considering, extending existing automatic handling equipment or introducing new machines.

This equipment is now used by almost the whole range of industry and among those who are taking automation still further are those concerned in the production of electric switchgear and motors, electric heating components, welding electrodes, cycle accessories, components for mechanical-handling equipment, internal combustion engines, bearings, starter batteries, sewing machines, and domestic appliances. Some of the most advanced plans are those of the oil companies for the automatic measurement and distribution of petroleum products to road and rail delivery vehicles.

Much of the production in these fields is being done by the transfer machine where the work piece is transferred automatically from station to station, both in-line and rotary. The use of computer-controlled machine tools, at least in limited application, is expected to be extended in the manufacture of precision instruments and engineering capital goods such as large electrical generators, pumping plant, and hydraulic turbines.

The main reasons given for the adoption of automatic techniques for production processes are reduced costs and increased output, most firms hoping to be able to reduce the labour content in their costs. A further reduction is hoped for in the more efficient use of raw materials and, by increasing rate of thoughput, some companies hope to be able to reduce the proportion of capital tied up in stocks and raw materials.

There is definite evidence that automatic equipment is being installed to overcome labour shortages, particularly in the sphere of skilled labour. It will, however, give rise to a shortage of its own and already both makers and users of automatic equipment are feeling the shortage of design technicians and of engineers trained in electronics and servo-mechanisms. A new class of technologist, the programmer, will be employed to prepare work for the computers and there was almost universal agreement that there will be a grave shortage of programmers.

The probable effect of increased automation on the labour force is, as one would expect, fewer unskilled labourers and many more skilled technicians of all sorts. This, of course, raises its own problem—where the skilled technicians are to come from. In addition to national efforts to increase the number of technicians, many firms are taking active steps to operate their own training schemes for operatives and maintenance men.

duction and to measure the time to tool failure, which is judged by visual appearance of the cut surface, or by the obvious breakdown of the cutting edge as indicated by sound or frictional heat.

Drilling tests have likewise been used, in which a standard drill is allowed to penetrate the material under test by the application of a constant load for a constant time, the variable being the depth of hole drilled. Apart from the difficulties contained in the above methods, different machining operations each have different criteria of machinability. For example, drilling is made easier with a certain microstructure, but a different structure is more suitable for turning operations and there appears to be little room for compromise. Reaming and cutting are susceptible to such other factors as non-metallic inclusions, whereas the indications are that such chip breakers are advantageous when turning. Chip formation and the ease in which swarf can be cleared from the cutting edge has a marked effect on machinability. High-speed photography has been applied to study the mode of chip formation, which it is thought is related to ' cutability ' of the steel.

A material is often labelled as being ' too hard ' to machine when in fact the difficulty is that it is too soft. When endeavouring to trace causes of poor machinability, one is invariably presented with either the forging or the tool that has broken down, but usually the cause, particularly if of a progressive and not a catastrophic nature, is to be found several components prior to the submitted sample. Much metallurgical examination is, therefore, in vain. These are but a few of the many reasons making measurement and defining of ' machinability ' very difficult.

Arising from the vast experience of production engineers, and in particular of those metallurgists who have painstakingly examined the cause of machine-tool stoppages, several undesirable conditions causing inconsistency have been recognized. Most are avoidable, or can be minimized.

Steel Defects

The principal methods of steelmaking producing stock for forging are Siemens open-hearth, electric-arc and Bessemer (which must be mentioned, but it is hoped is not regularly used for forging-quality production). High-frequency melting is used in a very limited field and the newer vacuum melting may find its place in certain forging requirements. The differences between these methods of steel production are well known, but it is worth mentioning some of the resulting conditions in the steel which are known to affect ultimate machinability.

The larger the cast, the greater the difficulty in controlling objectional features, but the larger the cast the cheaper the steel—a factor that must be balanced against savings from any increased machinability derived from smaller casts. Open-hearth casts of 100 tons are common, but vacuum casts can be spoken of in pounds, not tons. Apart from the size of cast, the type of lining used, whether acid or basic, the quality of scrap and base metal and the size of ingot and method of teeming, strongly influence cleanliness of the final steel product. Forging-quality steels are fully killed, a modification often involving ladle treatment. The amount and distribution of non-metallic inclusions, particularly those arising from the killing of the steel, can have a strong influence upon the final machinability.

Non-metallic Inclusions

It is not suggested for a moment that a steel completely free of non-metallics is desirable—in fact, evidence shows that the machinability of open-hearth steel is superior to ' purer ' forms by virtue of the chip-breaking action of these inclusions. On the other hand, the highly-abrasive aluminium oxides resulting from aluminium ' killing ' are detrimental in so far as they can decrease the useful life of a cutting tool by preferential abrasion, resulting in a lost edge, increased friction and ultimate galling and breakdown.

The amount of aluminium oxides in the steel is controllable and in good steelmaking practice can rarely be blamed as a main cause of poor machinability. It must be emphasized from the outset that most of the factors influencing machinability are often accumulative in their detrimental effects—very few having cancelling effects. It is, of course, realized that the majority of steel forgings are made from steels in which a first consideration must be ' forgeability ' with ' machinability ' as a secondary aspect. It is not accepted, however, that these two requirements are necessarily opposites. For a given ' forgeability ' there is too often unreasonable variation in 'machinability' of the same specification.

The advantages of non-metallic inclusions as chip breakers is deliberately exploited by the addition of insoluble phases—often supposed to give internal lubrication during cutting, though the significance of the latter compared with chip control has not been clearly demonstrated. Sulphur (with a suitable excess of manganese) is deliberately added to form the insoluble manganese sulphides in the En 1, 8, 202, series of ' free-cutting ' materials. Care must be taken to avoid formation of the brittle iron sulphide by ensuring the correct manganese balance. Selenium has proved to be even more effective than sulphur, particularly in high-tensile steels, but unfortunately the attraction of this element to the electrical and electronics industry, together with its disagreeable properties when being added to steel, has precluded its extensive use in the

steel industry. Lead has now been successfully tamed and is finding increased application in alloy as well as straight carbon steels. These are examples of deliberate additions of ' non-metallics ' to improve machinability. Sulphur has to be watched for such reasons as subsequent case hardening and heat treatment, but these objections are less in the case of lead when present in sub-microscopic dispersion and probably even more so in the case of selenium.

Cast ingots are fundamentally heterogeneous in their crystallographic make-up. As a result of cooling and nucleation on non-metallics, particularly the products of ' killing,' the ingot consists of massive columnar crystals normal to the external faces, enclosing a central volume of equi-axed crystals.

Moreover, the columnar crystals are definite in their internal pattern. The tree-like structure, known as dendritic, is typical of all ' as-cast ' metals. The dendrites vary from the equi-axed crystals, not only in orientation but in composition.

To break down this structure completely is the main aim of all subsequent cogging and hot working, but perfection can never be obtained. Variation of crystal size plus the influencing factors of such elements as phosphorus, lead to segregation in varying degrees. It is also suggested that reheating and cooling during processing can in itself aggravate this condition. The aim of complete homogeneity of structure is a source of constant research. The Americans have a name for it—they ' desegatize ' the steel.

The hope of complete consistency in machinability of a given composition is therefore made difficult from the birth of the steel, but accepting this limitation, some consistency can still be hoped for and even expected.

Grain Size

Discussion of ingots cannot be passed over without a brief mention of the effect of grain size—a factor also of importance is the subsequent heating of heat treatment of a forging. It is reasonably well established that a course-grained steel is easier to machine than a fine-grained. Grain size is the average number of equi-axed crystals in any unit area. There are objections to taking full advantage of this difference, which need not be gone into in connection with the subject matter. It is fundamental that above the critical temperature ' grains eat grains,' so that both time and temperature of heating are important, particularly in the high range necessary for forging. It is realized, of course, that a main requirement is to be able to forge the steel successfully and that forging tends to break down the crystal size. Excessive grain growth must be controlled, in fact there is no reason why this variable should not be eliminated completely. Good heating, good forging and correct cooling refines the grain which, as has already been mentioned, tends to reduce machinability. But do not let this tempt anyone in departing from correct forging technique or encouraging grain growth, because heat treatment is expected to give its correct results as well.

Composition

Probably the biggest single factor responsible for pronounced differences in machinability is the influence of composition. The composition of a steel is usually determined by physical strength considerations or other properties such as corrosion resistance and magnetic requirements. These physical requirements, of course, arise by design according to the stresses to be tolerated. The alloying elements most commonly used to effect modification of properties are nickel, chromium and molybdenum. Their influence even on small quantities on the basic iron-carbon alloy are profound. Some elements, such as boron, have an optimum effect when added in quantities as small as 0·0005%. Nickel and chromium, however except when used for purposes of either magnetic or corrosion modification, rarely exceed 5%. Such alloy additions must have commercial tolerances, and although small in actual quantity are appreciable as a percentage of the total alloy addition.

Nickel and chromium strongly influence the strength of the ferrite, which is usually in preponderance at the machining stage. Thus further variables must be tolerated by reason of chemical specification alone. The variation in the combined effects of these elements is also considerable—mainly because of their differing effect on the principal critical points, which in turn, determine the metallographic make-up resulting from heat treatment. It is fairly well established that the simpler uniform structures are far easier to machine than the more complex, the latter being far more susceptible to variation of forging or hot-working techniques, and in particular, to cooling rates when normalizing or annealing.

Obviously, engineering recognizes the main differences between alloy and carbon steels and does not demand the same machinability value for both. Alloy steels are also prone to strain hardening, another detrimental factor in cutting operations. Since the war, it has been shown by the development of the En 320, 350 and 360 series that relatively high nickel and chromium is not essential to produce the properties previously required of such steels as the En 33 to En 39 specifications. This change in composition has had a marked effect on some production rates despite differences still to be found as a result of the variations in their metallographic make-up. There is still a wide

scope, however, for the study of microstructure and its effect on machinability in those cases where the former is readily modified by slight changes of composition.

Heat Treatment

Variations in heat treatment are a main cause of unnecessary differences in machining performance, and it is sad to have to say that these variations often arise from a lack of knowledge of the theory of the process. It is fair to assume that, due to the efforts of metallurgists, the days of 'heat to cherry red and dip in water' should have died as surely as the phlogiston theory did. But alas, cherries are still growing and do not change in colour. To many, heat treatment is a necessary evil, a curse—completely unnecessary, and in any case they know the best way of doing it.

Initial crystallographic orientation, distribution, grain size and composition, are each and collectively responsible for the reaction of a steel to thermal treatment. It must be said that the variations arising from heat treatment often far outweigh those due to the other factors, and that these variations are in themselves greatly responsible for the greater inconsistencies in machinability. Today modern production must achieve at least two objectives simultaneously, namely to maintain dimensional tolerances and to produce at an economic machining rate. The complex and successful machine tool has to be 'set.' To do so, a batch, or at the most, two batches of forgings or bar stock are used as setting pieces. This determines tool rakes, lubricants, spindle speeds and feeds. It is often touch and go whether subsequent batches are worse than or better than the setting batch in performance, according to whether the setting batch was in its best or worst machinable condition. One never hears about improvement in performance, but plenty about deterioration.

With certain types of steel, it has been shown that, where a given composition can be produced in more than one metallographic condition, one structure is preferable for certain operations than another. This is clearly demonstrated in the high-carbon-chrome steels of the En 31 type, where sub-critical annealing, resulting in a spheroidized structure, is much more desirable than the lamina pearlite when turning operations are involved. Even with this structure, however, variation in cutting performance can be detected when the spheroids themselves vary unduly in size. Thus, in this case annealing treatment is very critical. Many forgings are machined in the normalized condition. In fact, large forgings depend upon accurate normalizing for their final physical properties. The object of normalizing is to restore a consistency of structure after deformation, grain growth or often for the removal of internal stress. It must be repeated that consistency is the only aim of a normalizing treatment. The process consists of completely redissolving the carbide in iron at a temperature above the upper critical, and cooling in air at a rate sufficiently slow to suppress transformation to martensite or the bainites, but rapidly enough to prevent the coarse pearlitic structures which can arise from the slower cooling process of annealing. Thus care at normalizing temperature is important and the rate of cooling can only be achieved if hot surfaces have equal chance of shedding heat. Large heaps of forgings, both when heated or cooled, result in a marked variation of normalized structure. This variation will be reflected in the ease and consistency of cutting in production. Similarly, if full annealing is the object, the rate of cooling must be fully observed.

By hardening and tempering a steel of suitable composition, not only can desirable physical properties be obtained, but consistency of machinability can be improved. The effect of segregation can be minimized by reprecipitation of the carbon from the austenite solution by quenching and can be further enhanced by correct tempering. Even more useful results can often be obtained by the use of isothermal treatments, that is, transformations controlled by time and temperature.

The best balance of all the properties of steel resulting from heat treatment is obtained by the correct formation of 100% martensite, followed by tempering. Equal hardnesses can be achieved either by correct hardening and tempering, or by slack quenching with or without further tempering. But the result, as measured by machinability, can be vastly different, nor, of course, are the physical properties balanced. Some steels are more susceptible to variation of such treatment than others. For example, the machinability of En 39 varies enormously with bar or forging finishing technique—enough to make the difference between high-speed machinability and impossible to cut, let alone maintain consistently accurate dimensions.

Because of a somewhat wide variation in British steel specifications, completely uniform thermal treatment is often made difficult, if not impossible, but this is not an excuse for increasing the difficulties by lack of attention to temperature, furnace-loading techniques, cooling arrangements, quenching facilities and tempering control. These factors are the enemies of satisfactory machinability and the champions of inconsistency.

Hardness

The main method of control of heat treatment, namely hardness testing, is perhaps the biggest pitfall. Hardness values, as measured by any of the

accepted methods, are rarely a guide to machinability. Let us quote an example of the difficulties of interpretation. The schleroscope—a rebound method—is used for testing large masses, such as forgings. The harder the metal, the higher the indicator bounces. But what if the test was carried out on rubber? The indicator would still bounce. Does equal bounce mean equal machinability? Referring back to annealed En 31, the difference in terms of hardness between the spheroidized structure, the laminar structure and a mixture of the two is not easily shown by indentation hardness methods. In the case of En 39, there is an optimum range below and above which machinability deteriorates considerably. Apart from this, the structural condition within this optimum range is very significant and will cause considerable variation in performance.

Straight-carbon steels and highly-alloyed steels can be heat treated to the same hardness range but their machining characteristics will be different.

Hardness must only be considered as a guide, and then only when the same composition and treatment is being tested. 'The softer—the easier' is far from true. Until some few years ago, 300 B.H.N. was often quoted as the limit of machinability, but today the machining of forged materials up to a tensile of 85 tons/sq. in. is quite normal practice—in fact, the finish obtained at the higher hardness range is often superior to that resulting from similar operations on softer materials.

Surface Phenomena

What other factors can affect the behaviour of steel forgings when being machined on a repetitive production basis? Surface conditions are of considerable importance. Incorrect furnace atmosphere can produce serious surface decarburization. A decarburized layer is pure ferrite—one of the most difficult, if not the most, of all metallurgical phases to machine. It is very soft, highly ductile and consequently difficult to shear. It clings to cutting edges, increases frictional heat and promotes welding of swarf aggregates to the tool edge. Decarburization involves the simultaneous cutting of a duplex steel. Obviously, cutting conditions cannot be correct for two different steels of widely differing composition and properties. Consequently poor finish and poor tool life result. In the same category, adhering scale is just as detrimental, being non-metallic and highly abrasive. Again machinability performance is seriously impaired and production stoppages increase.

Steel making, hot working, composition, forging technique, heat treatment, hardness testing and surface conditions have been briefly discussed in their relation to machinability. They each have their individual effects and yet can be accumulative. When uncontrolled, they all lead to inconsistency in machining.

Conclusion

What, then, can the drop forger do about all this? He can control those variables which occur within his processing. He can ensure that compositions are within those specified, that temperature and time at forging heat are correct and are held to a minimum, thus also controlling scaling, decarburization, burning and grain growth. He can carry out heat treatment correctly and where criteria, such as structural conditions, are known to be necessary, he can keep them within the optimum by suitable inspection. He will not be able to influence much those known causes of bad machinability due to steelmaking, but it is not necessary to add to them.

By contributing to a maintenance of quality, the emphasis will shift to other factors affecting machinability, which can be investigated according to their seriousness. The forging industry can play its part in ensuring the success of specialized machine tooling by making predetermined levels of operating efficiencies attainable, thus reducing costs and creating a demand for more forgings. If they do not—look out for an increased tendency to make use of fabrication processes such as welding, and copper brazing.

Electric-melting Exhibition

New ideas in electric melting are being shown to industry at an exhibition held by Birlec Ltd. in conjunction with the London Electricity Board, at the Board's premises in Nelson Street, East Ham, Birmingham, until March 21, admission free by invitation.

Principal exhibits are the new Birlec-Morgan electric diecasting furnace, the latest type of Birlec Tama tilting furnace and the Birlec Ajaxomatic holding and pouring unit for aluminium diecasting, operating under production conditions with a Herbert-Reed-Prentice diecaster.

The Ajaxomatic is designed to eliminate ladling by delivering predetermined quantities of metal directly into the chamber of the diecasting machine, ensuring greater efficiency of timing and metallurgical control. The rapid automatic operation of the Ajaxomatic enables the production of aluminium diecasting to reach the same level as that achieved with zinc. Similar in principle to the company's Tama channel-type induction melting furnace, it is rated at 20 kW. and has an average power consumption of 10 to 12 kW., with a useful molten capacity of 300 lb. It is simple to operate and gives greatly improved working conditions.

The Birlec-Morgan E.D.F. electrically heated crucible furnace also has a capacity of 300 lb. It is rated at 25 kW. and is fitted with fully-automatic temperature controls, giving constant performance with no quality variation in the metal. By the inclusion of an automatic time switch, costs incurred in starting up the plant before normal working hours are very much reduced. Also on show is a scale model of the latest Birlec Detroit rocking arc electric melting furnace.

INSTITUTE OF METALS

Secondary Metal Recovery discussed at Swansea

AT a meeting of the Institute of Metals held at the University College of Swansea last month, Mr. H. J. Miller, M.Sc., F.I.M., of the Metals Division of the Imperial Chemical Industries Ltd., dealt in an able manner with the position occupied by the secondary metals industry, one of great importance because of the large financial values represented by the uprising of scrap in various forms.

There is a wide dissemination of secondary materials and a multitude of interests involved, in the handling of such metals. In the majority of cases, scrap passes through many hands in the course of collection and grading which preceeds utilization. Statistics indicate that the proportion of virgin metal to scrap metal is in some instances in the ratio of 60:40 which is typical for copper and lead. With iron and steel, the ratio of scrap is on a higher basis. With some other non-ferrous metals the scrap ratio is of a lower order, such as with zinc and tin, which follows from the nature of the primary uses of these metals. It is estimated that the secondary metals industry approaches some 2 million tons/yr. of copper, 1 million tons/yr. of lead, and large tonnages of the other non-ferrous metals. It is important that it should be appreciated that these global figures refer to secondary materials in all forms and that they are not confined to old or demolition metal.

The three sources from which secondary metals are derived are the metallurgical and consuming industries, and from demolition operations. Actually, statistics are much confused because of the different practices in recording scrap and it is difficult to interpret figures from different sources, countries and industries, due to varying customs. The practice in the steel industry is to return the gross tonnage of steel ingots cast, including run-around scrap. The non-ferrous metals industry does not report its data in this manner.

Secondary Copper Scrap

Metallic scrap can be used direct whereas non-metallic scrap must be subjected to some form of pre-treatment or melting operations. Scrap comes from about 200 different compositions of copper and copper alloys, and it is customary for metal merchants to classify into about 30 different classifications, to suit the main branches of the industry. These broadly fall under the following headings:—(1) Gun metal castings and ingots, (2) brass castings and ingots, (3) extruded brasses, (4) wrought alpha brasses, (5) copper refined (fire refined), and (6) smelted into rough copper, followed by electrolytic refining or conversion into copper sulphate.

In these groups, there are several individual covering alloys of a wide range of main compositions or impurity tolerances. Scrap may be utilized in each of these according to the impurities present and other factors. With swarf, it is customary to remove water and oil by centrifuging, followed by magnetic treatment. With sheet mill cuttings, visual inspection only is generally applied and the material is then baled into briquettes of suitable weight. With old copper-wire scrap such as telephone lines, the only treatment is baling. In the case of cables of large size, it is possible to separate the armouring and lead sheath from the copper cores by mechanical methods and hence clean copper is recovered for use. In the case of small size cables, and those which are badly deformed, the only way of separating is by sweating in a sloping hearth furnace so that the lead is melted and runs away for external collection. The copper in this case is contaminated with lead and the uses are restricted. Scrap radiators are best treated by heating in a super-heated steam or a completely non-oxidized atmosphere so as to melt the solder and thus remove as much as possible. It will be appreciated that a considerable amount of labour is involved in obtaining the metals in forms in which they can be used to advantage.

The largest single use of copper-tin-zinc scrap material is for the production of gun-metal ingots to the various specifications given in B.S. 1400 which includes a wide range of compositions, the most popular variety of which is the 85/5/5/5 gun metal. For mixed gun metal and commercial brass scrap in fine forms this outlet is most useful. The zinc is volatilized in operations down to the desired limit of 5%, other oxidizable impurities are converted to oxides and pass into the slags. The manufacture of gun-metal ingots is a large activity, which is useful in consuming large amounts of mixed copper alloy scrap that would otherwise have to pass to smelters. Brass ingots and castings likewise provide important outlets for copper alloy scrap, though this market is more restricted.

The extruded brass industry is the largest single user of scrap, although in this country the fire refining of copper is of comparable importance, tonnage wise. Here, at the present time, the production of semi-fabricated products is about 130,000 tons/yr. out of 700,000 tons, say 20% of the total, with the copper content about 15% of the total. Virtually almost the whole of this copper content is derived from scrap. The prime reason

Continued on page 123

Series on Heat Treatment

Distortion and Cracking

F. D. WATERFALL

The large number of interrelated influences controlling distortion and cracking during heat treatment makes the subject a difficult one to present in an organized way. The author considers two main factors—change in shape and change in volume, and discusses ways of preventing the phenomenon. This lecture, the fourth of the lectures on 'Modern trends in the heat treatment of steel' given at the Wolverhampton and Staffordshire College of Technology, will be concluded in next month's issue. The author is with the Technical Service Department, Heat Treatment Section, I.C.I. Ltd., General Chemicals Division

THE subject of distortion and cracking during heat treatment is difficult to present in an organized way because of the large number of interrelated influences that control their incidence. Fundamentally two main factors must be considered: (1) a change in shape excluding any change in volume arising from transformations, which is affected by the dimensions of the part being treated, the method of heating and cooling, or support during treatment; and (2) the change in volume which is the result of the transformations occurring during hardening and tempering.

Let us consider the volume changes that occur during heating and cooling of steel. On heating, there is the inevitable thermal expansion, amounting to about 3% by volume when heating from room temperature to 850°C. This change takes place, during uniform heating, uniformly throughout the steel and can, with care, be accommodated without appreciable distortion. On the other hand, non-uniform heating results in non-uniform expansion with attendant stress and distortion on heating. The formation of austenite from pearlite on heating through the Ac_1 point results in contraction in volume. Conversely, an increase in volume occurs when austenite transforms to pearlite on slow cooling. However, at increased rates of cooling the austenite-pearlite inversion is suppressed in part, or entirely, and is ultimately replaced on small sections which are rapidly cooled by the austenite-martensite transformation, which gives rise to an increase in volume of approximately 1% at a low temperature and within a narrow temperature range. These changes are shown diagrammatically in Fig. 1.

Now to examine these changes in more detail. Take a 1% carbon steel sphere heated to 700°C., *i.e. below* the Ac_1 temperature, thus remaining pearlitic. When this is quenched into water the exterior layers will immediately cool to the temperature of the water and will endeavour to contract as far as possible. Beneath these layers are regions whose temperature has not fallen as much because they are more remote from the surface whence the heat is being extracted—thus the contraction of these regions is delayed. The exterior surface is therefore exposed to a bursting force because it is shrinking (in a sphere) on to an unyielding core. As the temperature difference between edge and centre falls, the central regions undergo contraction and the bursting pressure is thereby removed; indeed, the tensile stresses are replaced by compressive stresses in the skin. If a sphere of steel is heated rapidly the surface expands, subjecting the underlying layers to tension. (In very large sections, such as ingots, rapid heating can cause cracking due to the stresses resulting from differential expansion of surface and inside layers.)

When a similar sphere is quenched *from above* the critical temperature the external skin first *shrinks* but later transforms to a hard brittle layer of martensite, with accompanying *expansion*. The layers immediately beneath this skin transform progressively to martensite when they cool through the 200 to 100°C. range, with a further increase in volume. When this 1% carbon-steel sphere is,

produce appreciable plastic deformation. Therefore it is imperative that parts with length appreciably greater than cross-section should be well supported during heating, otherwise they will deform under their own weight. An illustration of the deformation produced by low stresses is given by A. L. Prances (*Steel*, January 26, 1953), in which tests were carried out on bars of steel 10 in. by 2 in. by $\frac{1}{2}$ in. placed flat on supports 9 in. apart and loaded at the centre of the span. They were heated for $1\frac{1}{2}$ h. at 900°C., followed by slow furnace cooling.

As is shown in Fig. 3, the amount of distortion increases rapidly with increase in surface stress, but even at low stresses of the order of a few pounds per square inch the distortion is appreciable. When reducing the free span by provision of intermediate support, or by increasing the vertical section, *i.e.* by placing the bars with the 2-in. dimension vertical, distortion is considerably reduced under the same loads. This example emphasizes that distortion can occur during heating and cooling even at slow rates when the lack of proper support introduces bending stresses.

Diecasting dies, such as that illustrated in Fig. 4, would distort if heated to hardening temperature too rapidly. In muffle practice, the part should be properly supported in a relatively cool furnace and raised with the furnace to the hardening temperature. In the salt bath method, dies are heated in air to 400°C., complicated shapes transferred to salt at 750°C., and then dies and salt raised together to the hardening temperature prior to quenching.

Stresses in the Material Prior to Heating

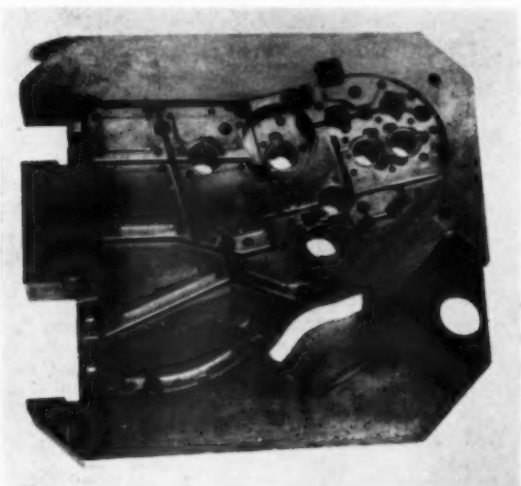
The above conditions are aggravated by the presence of internal stresses present in the material before heat treatment. In cold-drawn bar large and unevenly distributed stresses are frequently present. Forgings and heavily machined parts are also in a stressed condition. These stresses should be relieved by a sub-critical anneal, or by normalizing, before final machining. Should the part contain stresses prior to heating, these will cause distortion during heating. Such stresses can result from lack of a normalizing treatment after, say, forging or from use of cold-drawn bar stock, or again appreciable stress results from heavy cuts during machining. Intricate parts with close dimensional tolerances should, as a rule, be stress relieved at 650°C., prior to final machining.

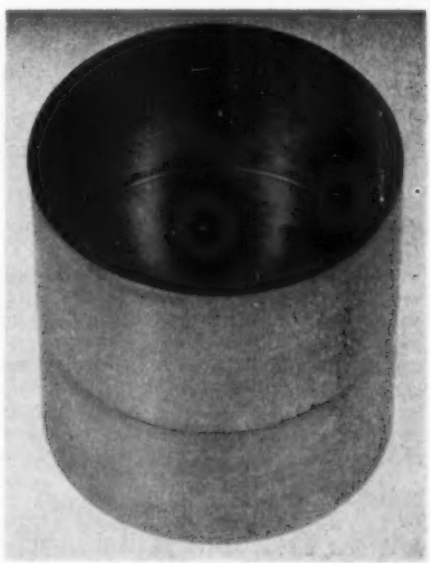
Influence of the Martensite Formation

We have previously given an example of the increase in volume occurring when a 1-in.-dia. bar of carbon tool steel is quenched. In Table II the effect of specimen size and type of tool steel on the volume change is shown. This table is taken from J. Y. Riedel, *Metal Progress*, 1950, pp. 853-859. Note that, although for small pieces of carbon tool

Fig. 4 (left) *Typical diecasting die likely to distort if heated too rapidly to hardening temperature*

Fig. 5 (right) *Cracking in a component consisting of a solid base attached to a thin cylinder with a sharp notch at the change in section*





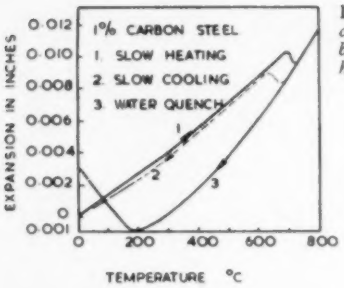


Fig. 1 *Dilation curves in 1% carbon steel during heating and cooling*

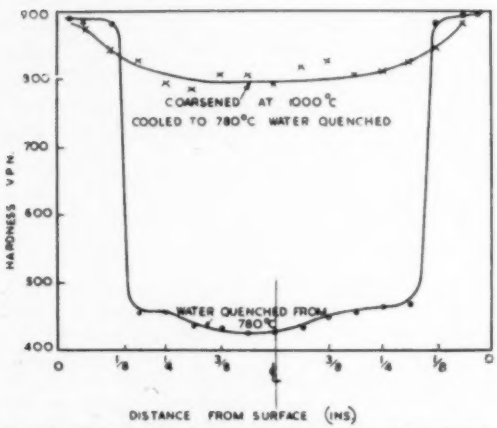


Fig. 2 *Effect of grain coarsening on depth of hardening, thus volume of martensite formed, in bars of 1% carbon steel*

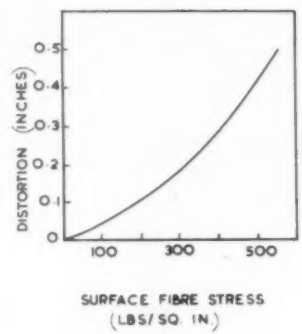


Fig. 3 *The effect of surface-fibre stress on distortion of bars 10 in. by 2 in. by ½ in. placed flat on supports 9 in. apart and loaded at the centre of the span, then heated for 1½ h. at 900°C. in a muffle, followed by slow cooling in the muffle (A. L. Prances, Steel, January, 1953)*

say, 1 in. or more in diameter, the central regions will not expand appreciably because the hardenability of the material is low, so pearlite will form from the austenite in the core with only slight expansion during transformation. As this pearlite cools from temperature of formation to that of the quenchant it shrinks in volume, resulting finally in compressive stresses in the hardened surface layers.

Turn now to a cylindrical bar of 1% carbon steel, 1 in. dia. by 12 in. long, quenched in water from 780°C.: the volume increase was 0·45%. It would consist, as hardened, of a shell of martensite surrounding a core of pearlite. If more martensite could be formed during quenching the volume increase would be greater. A similar-sized test piece 1 in. dia. by 12 in. long, from the same bar of 1% carbon steel, was first grain coarsened by heating to 1,000°C., then cooled to 780°C., and water quenched. Its volume increase was 0·75%, *i.e.* greater than that of the bar heated to and quenched from 780°C., because the material grain coarsened before quenching had hardened to a greater depth. Fig. 2 shows the depth of hardening in the two bars, and Table I summarizes the dimensional changes observed.

TABLE I *Effect of grain coarsening on volume change during hardening of 1% carbon steel*

	Length movement, inches	Diameter movement, inches	Volume increase, %
12 in. long by 1 in. dia. 1% carbon steel, water hardened from 780°C.	−0·018 (0·15%)	+0·0025 (0·26%)	0·35
12 in. long by 1 in. dia. 1% carbon steel, heated to 1,000°C., cooled to 780°C., and water quenched	−0·001 (0·01%)	+0·0035 (0·36%)	0·75

A fine-grained shallow hardening steel in all but small sections alters less in volume during quenching than a coarser-grained deeper-hardening steel of the same analysis.

The fact that retained austenite is more dense than the annealed (pearlitic) structure from which it is derived suggests a method of reducing volume change during hardening of parts in alloy compositions where appreciable austenite retention is possible. By choosing conditions where austenite is retained, *i.e.* by increasing the quenching temperature, the increase in volume due to formation of martensite may be balanced against the decrease in volume brought about by the presence of austenite, always provided the requisite hardness is obtained in spite of austenite retention.

Stresses during Heating

It is well known that hot steel is less strong than cold steel. In fact, at normal heat-treatment temperatures the yield strength of many steels is almost negligible, *i.e.* only a very small load will

The Re-nitriding of Steel

G. J. COX, A.I.M., A.C.T.(Birm.)

It has previously been usually accepted that a nitrided steel, unlike a carburized steel, cannot be restored to the full hardness after annealing. It is attempted to show in this article that this limitation, whilst true for aluminium-chromium-molybdenum steels, is not applicable to chromium-molybdenum or chromium-molybdenum-vanadium steels. The author, now of Mond Nickel Co. Ltd., Development and Research Laboratory, was previously with the Heat-treatment Development Laboratory of Joseph Lucas Ltd. The article, the first part of which appeared last month, is concluded in this issue

Experimental Work: Part II

THE SAMPLES for the first treatment consisted of small bars of steels A, B and C which had previously been nitrided for 72 hours at 500°C. These specimens were heated for eight hours at 1,000°C. in a sealed box through which argon was passing. This treatment was used as it had already given the best results so far obtained.

After de-nitriding, the bars were lightly polished, re-nitrided and then taper ground to enable depth-hardness plots to be made; two bars were also hardened and tempered before re-nitriding. The results of this test are shown in Figs. 3, 4 and 5 and in Table IV, from which it is clear that the steels which have chromium as the predominant alloying element re-nitrided quite satisfactorily. The aluminium-containing steel again failed to respond.

Having established that at least one treatment could be successful, the object of the next group of tests was to find a de-nitriding method more suitable for production use. The aim was to reduce the temperature and time of treatment and also to find a substitute for argon as a protective atmosphere. It was decided to treat test bars, therefore, both in and above partly burnt charcoal. When actually in the charcoal, the bars would be subject to some carburizing effect. When held just above it some protection should be obtained from the atmosphere created. The latter method, of course, is one frequently used in the commercial hardening shop for the protection of alloy tool steels, especially those of the high-carbon high-chromium type; the familiarity of this technique recommended it for experiment. The need for protection, of course, will be appreciated, as a brittle surface results when decarburized steel is nitrided. The fact that the test bars were enclosed in nickel-chromium pots would allow the cooling rate to be fairly slow and thereby lower the resulting surface hardness.

Steel B was used exclusively for the ensuing experiments, as a further supply of steel C was not available. It was felt that, due to the similarity of composition between these two materials, they could be expected to respond similarly. Also the hardening and tempering treatment before re-nitriding was now omitted, as this had been shown to have no effect on the final result.

Tests were carried out, therefore, for various

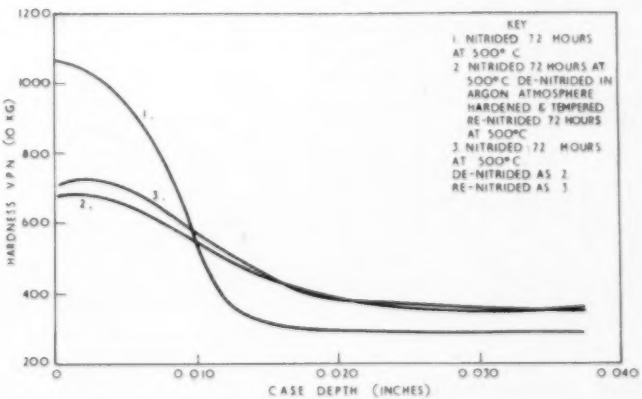


Fig. 3 *Depth-hardness curves for steel A*

TABLE II *Effect of specimen size and composition of alloy on volume change during hardening* (*J. Y. Riedel*, Metal Progress, 1950, *pp.* 853-859)

Steel	Size of specimen	Hardening treatment, °C.	Volume change, %
Carbon tool steel	¾ in. dia. by 1¼ in.	780 brine	+0·9
	1¼ in. dia. by 3 in.	,, ,,	+0·5
	¼ in. wafer cut from centre of 1¼ in. dia. by 3 in. piece after hardening	,, ,,	+0·3
Mn oil hardening	½ in. sq. by 1 in.	800 oil	+0·6
Si-Mn	½ in. sq. by 1 in.	885 oil	+0·6
Air hardening 5% Cr 2% C/ 12% Cr	½ in. sq. by 1 in.	970	+0·3
	½ in. sq.	1,010	−0·1

steel the volume change is as much as 0·9%, larger sections of the same material change less in volume because the larger sections do not harden throughout. Most applications of carbon tool steels involve sizes which do not harden throughout. The reason that water-hardening steels distort more than oil-hardening steels is that the major part of the distortion arises, not from the volume change due to formation of martensite in itself, but from stresses set up during quenching when part of the component cools—and forms martensite—whilst other parts are still hot and plastic.

From the foregoing, it follows that a given part made in a steel requiring water quenching to harden will distort more than the same part made in a steel capable of being hardened by oil quenching. Again, the same part made in a steel capable of being hardened by air cooling from the hardening temperature will generally distort less than when made in material requiring quenching in either oil or water. In other words, the more severe the quench the greater will be the thermal stresses, and thermal stresses during quenching have a greater influence on distortion than the actual volume of martensite formed.

Effect of Tempering Martensite

The tempering of martensite causes contraction and thus offsets somewhat the expansion resulting from martensite formation. Table III gives some data on this effect. In theory the size change resulting from martensite formation could be eliminated by tempering at a sufficiently high temperature, but this, of course, would generally result in the part being too soft for the intended application.

Effect of Shape

The most important single factor is unevenness of section, and it cannot be over-emphasized that

TABLE III *Volume changes which occur during tempering of hardened steel*

Steel	Volume change on hardening, %	Volume change after hardening and tempering at 200°C., %
Carbon tool steel.. ¾ in. dia. by 1¼ in.	+0·9	+0·8
Mn oil hardening	+0·6	+0·45
Si-Mn shock resisting	+0·6	+0·5
Air hardening (5% Cr)	+0·3	+0·2

where changes of section are inevitable it is desirable to reduce these changes to a minimum and blend thick and thin sections with ample radii. The effect of a notch is always to cause a concentration of stress in its vicinity. The stress concentration increases with depth of the notch and inversely as the radius of the root of the notch. Although this fact is nowadays generally appreciated, constant vigilance should be exercised to see that it is carried out in practice. An extreme example which resulted also in cracking is the part shown in Fig. 5, consisting of a thin cylinder attached to a solid base. The original diameter of the part was 2·550 in.; after hardening the diameter of the thick section was 2·501 in. and that of the thin section 2·507 in.

Mode of Quenching

Hardening of cylinders whose length is considerably greater than the diameter provides an interesting example of the influence of mode of quenching on distortion. The best method of quenching carburized En 32 steel rollers used in textile printing —1 in. dia. by 2 ft. in length—is by rolling them down skids into the water quenching tank, rather than quenching slowly with the bar in the horizontal, vertical, or inclined position. When a cylindrical bar of this length is quenched vertically it is practically always found that the diameter increases and the length contracts slightly. An explanation of this effect may be given in the following way. As the end enters the quench, it is hardened and the circumference tends to expand. As the quenching of the surface proceeds the expansion of the surface 'sucks in' the hot plastic steel and therefore the length is reduced before the upper end can be hardened and complete the hard unyielding skin of martensite. This line of reasoning suggests that some measure of control of variation in dimensions is possible by altering the speed at which the bar is introduced into the quench bath when quenching is vertical.

To be continued

TABLE IV *De-nitriding experiments with steels A, B and C*

Steel	De-nitriding treatment	Surface hardness after de-nitriding, V.P.N.		Surface hardness after oil quench and temper, V.P.N.		Surface hardness after re-nitriding, V.P.N.	Nitriding cycle	Depth hardness curve reference
		10 kg.	30 kg.	10 kg.	30 kg.	10 kg.		
A B C	8 h. at 1,000°C. in an argon atmosphere	260 371 560	275 375 —	380 380 450	400 397 475	— 894 894	72 h. at 500°C.	3 4 5
B	4 h. at 1,000°C. in partly-burnt charcoal packed in a nickel-chromium pot	(1) 620 (2) 680	— —	— —	— —	813 835*	,,	6 6
B	4 h. at 1,000°C. placed above partly-burnt charcoal packed in a nickel-chromium pot	(1) 374 (2) 397 (3) 350 (4) 375	— 430 — —	— — — —	— — — —	858 882 847 835*	24 h. at 500°C. 40 ,, 48 ,, 72 ,,	7 7 – 7
B	2 h. at 1,000°C. placed above partly-burnt charcoal packed in a nickel-chromium pot	(1) 350	—	—	—	813*	72 h. at 500°C.	8
B	4 h. at 900°C. in partly-burnt charcoal packed in a nickel-chromium pot	(1) 240	—	—	—	600	,,	8
A B	2 h. at 820°C. in neutral salt	(1) 500 (2) 250	— —	— —	— —	580 350	,,	8

* Showed evidence of inferior surface

1,000°C. gave marginal results (Fig. 8). It is interesting to note how the two ineffective de-nitriding treatments, *i.e.* the Merten method and treatment at 900°C., lead to the same shape of depth hardness curve after re-nitriding (Fig. 8).

Microscopic Examination

Referring to the first section of the experimental work on steel A, Fig. 9 shows the structure near the surface after nitriding and heating in argon for 17 hours at 1,000°C. It is evident that all the nitrogen has not been removed. After re-nitriding the case has a reasonably normal appearance; a modified white layer (Fe_2N) can be seen on the steel surface (Fig. 10).

In the second section of the work dealing with steel B, Fig. 11 shows the surface structure after nitriding and then de-nitriding in charcoal for four hours at 1,000°C. The high surface hardness can be seen to be due to bainitic transformation products and retained austenite is also present. Fig. 12 shows the unetched structure after de-nitriding above partly burnt charcoal for four hours at 1,000°C. Here the remains of a white layer can be seen. In the etched condition (Fig. 13), it is apparent again that some nitrogen remains in the steel, a chain-like precipitate of iron nitride, possibly Fe_4N, being visible.

The re-nitrided structure of this sample is shown in the unetched condition in Fig. 14 and in the etched condition in Fig. 15. A speckled zone of about 0·001 in. deep is visible, but the etched case

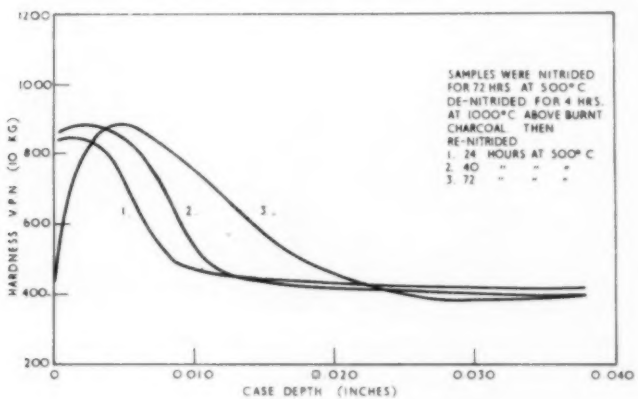
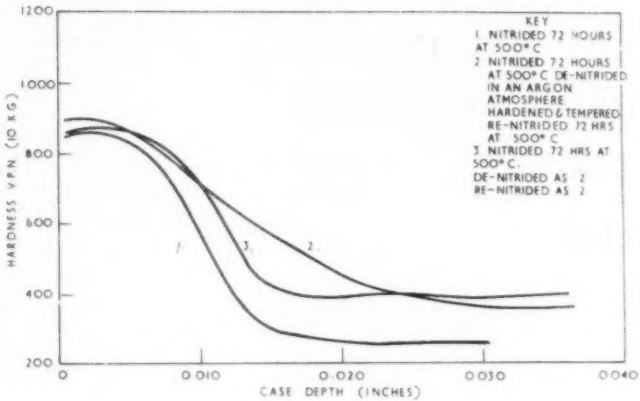


Fig. 7 *Depth-hardness curves for steel B*

Fig. 4 *Depth-hardness curves for steel B*


KEY
1 NITRIDED 72 HOURS AT 500° C
2 NITRIDED 72 HOURS AT 500° C DE-NITRIDED IN AN ARGON ATMOSPHERE HARDENED & TEMPERED RE-NITRIDED 72 HRS AT 500° C
3 NITRIDED 72 HRS AT 500° C. DE-NITRIDED AS 2 RE-NITRIDED AS 2
HARDNESS VPN (10 KG)
CASE DEPTH (INCHES)

times at 900 and 1,000°C. with the sample bars both in and above charcoal. In these latter tests the bars were laid on wire mesh in a nickel-chromium carburizing pot above a bed of partly-burnt charcoal about 2 in. deep, the lids were placed on the pots and they were then heated in an electrical heat-treatment furnace. The original de-nitriding method suggested by Merten was again tested to provide a comparison and here one further experiment using steel A was made. The results are given in Table IV

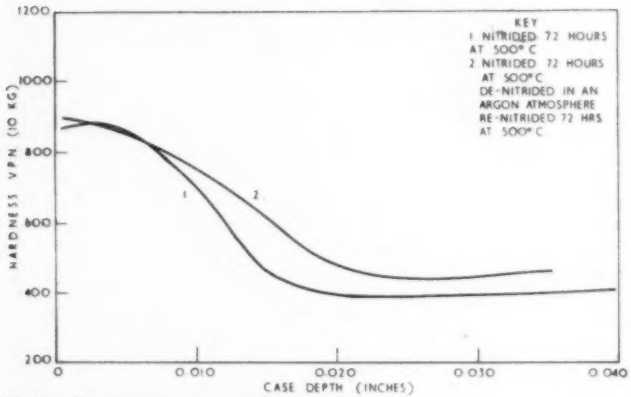

KEY
1 NITRIDED 72 HOURS AT 500° C
2 NITRIDED 72 HOURS AT 500° C DE-NITRIDED IN AN ARGON ATMOSPHERE RE-NITRIDED 72 HRS AT 500° C
HARDNESS VPN (10 KG)
CASE DEPTH (INCHES)

Fig. 5 *Depth-hardness curves for steel C*

and the accompanying depth hardness curves. From these can be seen:—(*a*) The Merten process of de-nitriding was unsuccessful with steel B (Table IV) and it was confirmed that it is ineffective with steel A (Table IV and Fig. 8).

(*b*) De-nitriding of steel B either in or above charcoal allows a satisfactory re-nitrided hardness to be obtained (Figs. 6, 7 and 8). The case depth is related to the time of treatment as with normal nitriding (Fig. 7).

Because of the carburizing effect the 'as-de-nitrided' hardness is higher when the samples are treated in charcoal at 1,000°C. and de-nitriding above charcoal is, therefore, preferable (Table IV). It was found quite easy to hacksaw through these samples. Generally, it should be remembered that nitrogen increases the hardenability of steel and, whatever the technique used, a slow cooling rate from the de-nitriding temperature is desirable. In some of the tests with steel B a soft skin was detected after re-nitriding (Table IV, Figs. 6, 7 and 8).

It seems that a temperature of 900°C. is not sufficient to give effective de-nitriding, whilst a shorter time of two hours at

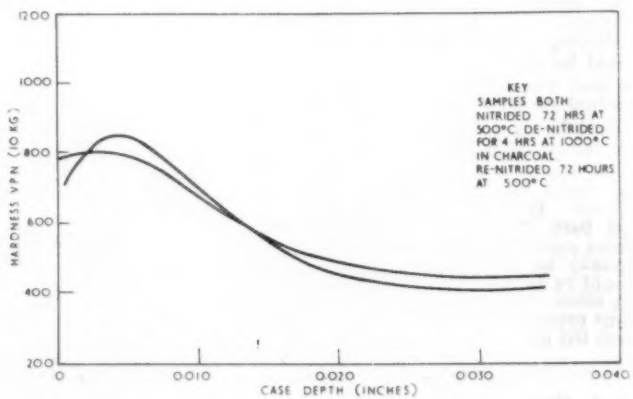

KEY
SAMPLES BOTH NITRIDED 72 HRS AT 500°C. DE-NITRIDED FOR 4 HRS AT 1000°C IN CHARCOAL RE-NITRIDED 72 HOURS AT 500° C
HARDNESS VPN (10 KG)
CASE DEPTH (INCHES)

Fig. 6 *Depth-hardness curves for steel B*

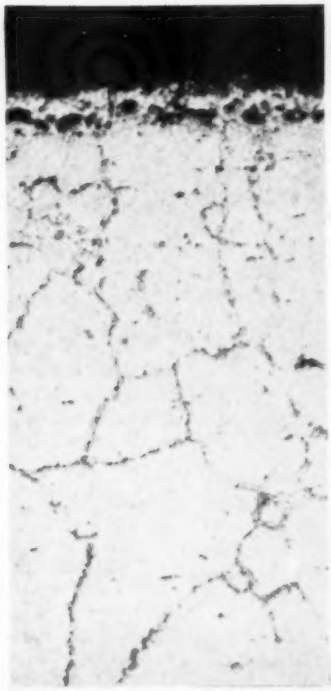
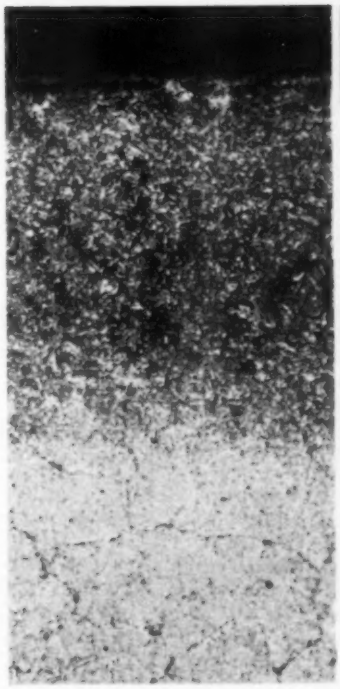


Fig. 12 (top left) *Steel B. Nitrided then de-nitrided above charcoal for 4 h. at 1,000°C.* × 200 *Unetched*

Fig. 13 (top centre) *As Fig. 12* × 200 *Etched*

Fig. 14 (top right) *Steel B. Nitrided, de-nitrided for 4 h. at 1,000°C., then re-nitrided for 24 h. at 500°C.* × 200 *Unetched*



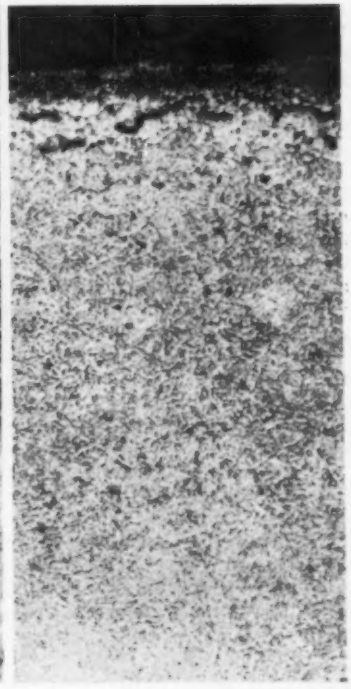


Fig. 15 (left) *As Fig. 14* × 200 *Etched*

Fig. 16 (right) *Nitrided, de-nitrided for 4 h. at 1,000°C., then re-nitrided 72 h. at 500°C.* × 200

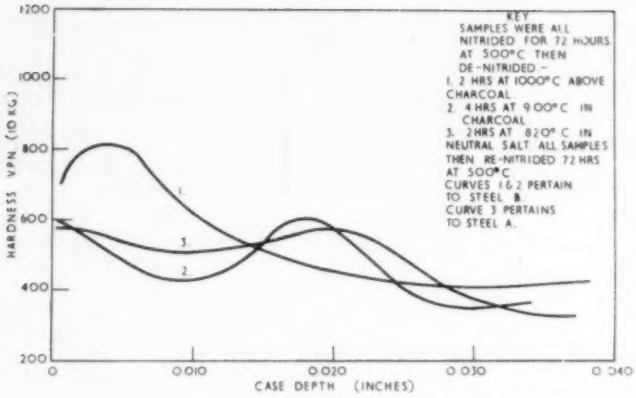


Fig. 8 *Depth-hardness curves for steels A and B*

has a fairly normal appearance. Another sample after having been nitrided, de-nitrided above charcoal, and then re-nitrided showed a dark phase on the surface (Fig. 16). This particular specimen is related to curve 3 of Fig. 7 and the effect, which is about 0·002 in. deep, corresponds to the softer skin revealed on the depth hardness curve. Such an effect is obviously undesirable. The factors governing its formation are not known but, as noted above, from Table IV it can be seen that several specimens suffered from this softer skin after re-nitriding. It may be that what has been observed is either (*a*) an oxidation product or a phase resulting from decarburization during the de-nitriding treatment, or (*b*) porosity and surface exfoliation brought about by the nitrogen gas diffusing from the surface.

With these samples the diamond hardness impressions were not clearly defined and this indicates an inferior surface. To obtain a satisfactory impression a heavier polish had to be applied. Obviously, when this type of surface results, a heavier grinding allowance is necessary. With the other specimens the impression obtained after the normal light polish was clear and sharp, which fact was taken to show that the surface was of good quality.

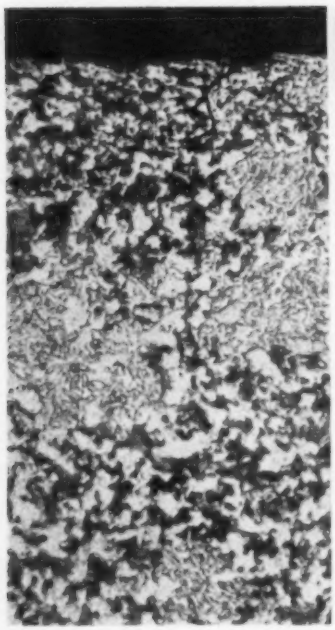


Fig. 9 *Steel A. Nitrided for* 24 *h. at* 500°*C. then reheated in argon for* 17 *h. at* 1,000°*C.* × 500

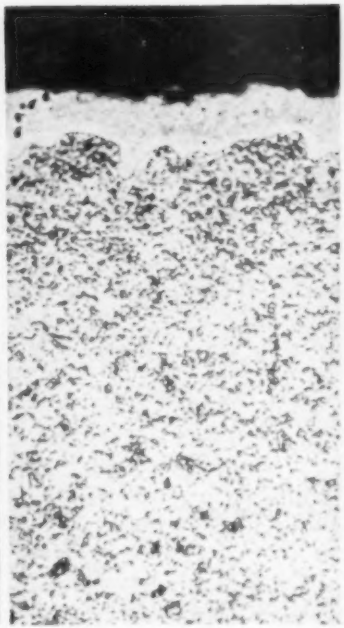
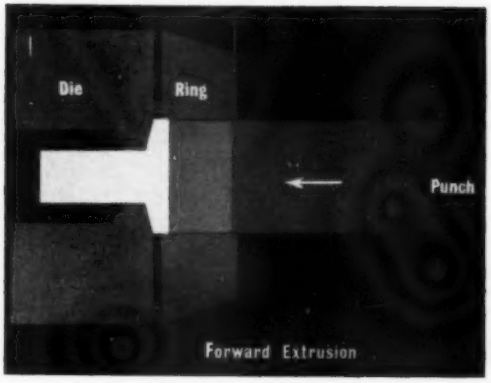
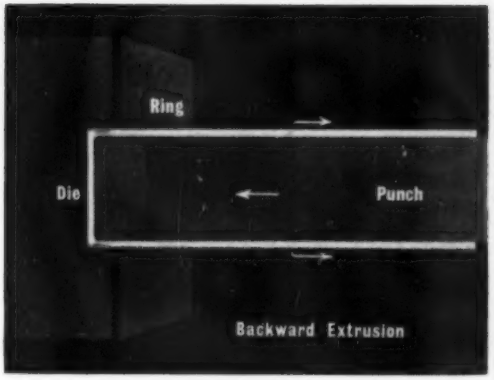


Fig. 10 *Treated as Fig.* 9 *then renitrided for* 60 *h. at* 500°*C.* × 500

Fig. 11 *Steel B. Nitrided then de-nitrided in charcoal for* 4 *h. at* 1,000°*C.* × 200



Impact Extrusion



This article on cold impact extrusion is based on a lecture given by H. W. Byles, of Wickman Ltd., to the Coventry section of the Institution of Production Engineers in January. Mr. Byles also discusses the special case of extruding steel parts

IMPACT extrusion, though a relatively new technique, has been established in the U.K. for some years, and the number of parts produced by this method now runs into millions per week.

Impact extrusion, cold extrusion, cold forging, and cold flow pressing all mean much the same thing, *i.e.* the conversion of metal blanks into shapes of another kind through plastic deformation by a fast application of pressure. Cold flow simply means that the blanks are normally fed at room temperature, but any temperature below the recrystallization zone of the particular material being used would be suitable.

The process is basically simple, and has three main advantages, the most important being economy of material. The volume of metal in the blank is generally the same as the volume of the finished part and, where trimming is necessary after the press operation, only a very small percentage of metal is lost.

The second advantage is that parts made by impact extrusion are stronger than those made by conventional means, owing to the fact that the grain flow is related to the shape of the part by the plastic deformation which takes place in the press. The speed of production is the third main advantage of impact extrusion, and is inherent in the process. The production rate is often the number of strokes of the press per minute, which may be about 60 to 100 in favourable circumstances.

The process has a wide range, with the emphasis at present chiefly on the extrusion of aluminium and other non-ferrous metals. All shapes and sizes of rigid and collapsible containers are currently in production in these metals. Various problems and difficulties have restricted the use of ferrous metals on a large scale, but much research and development work, carried out chiefly in Germany and the U.S.A., indicates that the field for extrusion of ferrous metals may well be wider than that occupied by non-ferrous extrusion.

Basic Methods and Appliances

There are three methods of impact extrusion of which the most commonly used at present is backward extrusion, where the metal flows in the opposite direction to the movement of the punch. The second method is forward extrusion, where the metal flows in the same direction as the punch. The third is a combination of the two, where extrusion takes place in both directions. These divisions of the process facilitate the production of components of all shapes and sizes, depending only on the type of tools employed.

A typical tool set for the backward extrusion of simple square-section aluminium containers consists of a punch and two-piece die. The punch, flat in the centre, is chamfered at the edges to give better metal flow, and a small relief angle is provided behind the edge to prevent the component sticking

Relation of Results to Previous Work

It will be seen from the results shown here that the 3% chromium steels can be de-nitrided and then satisfactorily re-nitrided. As far as is known the re-nitriding of these steels has not been investigated by other workers. Apart from this, how are the results of the earlier investigators to be assessed ?

It is felt that, although Merten did show that a nitrided steel could be softened, when using his method the removal of nitrogen cannot have been complete and a chemical process was not involved. It is not easy to come to conclusions on his claims to successful re-nitriding, as no figures are given either in the original paper or in his subsequent discussion on the paper of Sergeson and Deal. He may have re-nitrided the steel quite easily, but only after the original case had been largely removed.

Sergeson and Deal showed that re-nitriding was not possible on the original softened surface. The 3% chromium steels were not tested, but their curves showing loss of nitrided hardness as a function of de-nitriding time probably give a reasonably true indication of how any steel would respond. To obtain softening in a reasonable time a temperature of the order of 950 to 1,000°C. was shown to be necessary.

Talbot's remarks as such are quite correct, but are subject to the confusion that exists over the various meanings of the term re-nitriding. His statement that a properly hardened steel can be re-nitrided without detriment is confirmed by the author's experience.

Conclusions

1. The 3% chromium-molybdenum and chromium-molybdenum-vanadium steels can be de-nitrided by heating to a temperature of about 1,000°C. for a period of two to four hours in a protective medium. Using this method, the steels can be softened to approximately 350 to 400 V.P.N. at which hardness they may be machinable. Afterwards, re-nitriding can be accomplished on this same surface and the full hardness and case depth will be obtained. It is advisable, of course, to lightly clean the surface before re-nitriding.

2. Aluminium-bearing steels do not respond to this treatment.

3. The method of de-nitriding proposed by Merten is not effective on either aluminium-containing steels or on 3% chromium steels.

4. On some occasions after re-nitriding chromium steels, the extreme surface may be slightly softer than the underlying case and microscopic examination has shown that this surface may be of inferior quality. Consequently it is advisable if possible to remove 0·001 to 0·002 in. by grinding. This grinding is in any case necessary in normal nitriding practice. Generally it is obvious that the quality of a re-nitrided case will be somewhat inferior to a normal case. However, as long as a small grinding allowance is possible, the results should be satisfactory for most purposes.

5. It has been suggested that the results obtained in this investigation stem basically from the fact that (*a*) the nitride-forming elements are in the combined state after one nitriding treatment, and (*b*) chromium nitride is a less stable compound than aluminium nitride. Thus, after heating the steel to a moderately elevated temperature, chromium nitride dissociates and the chromium goes back into solution in the ferrite. On the other hand, in steels where aluminium is the principal alloying element, due to the stability of aluminium nitride, only a partial regainment of hardness will be obtained. In view of our ignorance of the mechanism of nitride hardening such a proposition can only be regarded as a tentative explanation. It is suggested that carefully controlled experiments should be made in an investigation of the loss of nitrogen from nitrided steel—such work could lead to a better understanding of the process.

6. Finally a clear distinction should be made between the different cases of re-nitriding. Thus:—
(*a*) Re-nitriding of a steel which has already been satisfactorily nitrided, but perhaps having a few areas on the surface which have been accidentally protected, can be carried out satisfactorily.

(*b*) Re-nitriding of a steel which has not been properly nitrided in the first treatment—due, for example, to too high a nitriding temperature or poor gas circulation—will not be successful.

(*c*) Re-nitriding of a nitrided steel which has been subsequently de-nitrided can, as has been shown, be carried out satisfactorily with some steels.

Acknowledgment

The author wishes to thank Joseph Lucas Ltd. for permission to publish this paper.

98% Grade Vanadium Oxide

A 98% vanadium oxide has been added to the list of alloys and metals available from the Alloys Division of Union Carbide Ltd. The new grade represents a marked improvement over former grades which average 86 to 89% V_2O_5. The reduction of alkali oxide content to not more than 2% is important to furnace operations because of the appreciable elimination of fume hazards caused by these oxides. The 98% vanadium oxide also offers advantages in reduced sulphur content, silica content and other contaminants which have a direct bearing on the production of high-quality vanadium steels.

Vanadium oxide (98%) is now available in either a dense fused form suitable for direct addition to an alloy furnace, or in granular form, from the Alloys Division of Union Carbide Ltd., 103 Mount Street, London, W.1.

on the punch. The die is made up of a base plate and ring, with the base recessed to take in the bottom corner radius up to the junction with the straight wall. Another essential part of the process is the metal blank which must be a good fit in the die and have a slightly rough surface to carry the lubricant necessary for extrusion.

Fig. 1 shows an example of a press producing simple cylindrical containers. This machine, made by Maschinenfabrik Herlan, Germany, is one of a range of horizontal toggle presses with pressures from 34 to 800 tons in ten sizes. All are capable of very high production rates. The press, which is a relatively small one, operates by toggle action and gives consistently smooth strokes up to about 65/min. A carrier mechanism feeds the blanks into the die, the movement being interlocked with that of the punch. The component is removed from the punch by a stripper and falls on to a conveyor which ejects it into a box. Both end and walls of the extruded parts are then checked for thickness. Inspection of the component also gives an indication of the wear on the die.

Blanks may be of any shape, and oval or polygonal blanks are quite common. In Britain, impact extrusion is chiefly applied to the production of hollow parts in aluminium, especially collapsible tubes such as toothpaste tubes. These are produced in basically the same way, using a domed blank with a hole in the centre. Forward extrusion forms the nozzle, and backward extrusion forms the body of the tube. Tubes with a blind end are produced by providing a spring-loaded plunger in the die base, which yields enough to allow the thin membrane of metal to remain over the nozzle. Collapsible tubes represent the severest form of impact extrusion because of their thin walls, and the pressure required to form them is much higher than that required for forming rigid containers.

The pressure required for impact extrusion is decided by many factors, wall thickness being one of the most important. Reducing wall thickness from 3 to 0·3 mm. increases the pressure required from 4·5 to 9·6 tons/sq. cm. for aluminium; with copper, the figures are almost double. The pressures required for impact extrusion of ferrous metals are very much higher.

Steel Extrusion

Extruded steel parts can be divided into two broad groups, solid bodies and hollow parts. The hollow parts may have open or closed ends and straight sides. They may also have stepped bodies, or a combination of different body shapes with open or closed ends. The solid parts, usually produced by forward extrusion, may also be subdivided into straight-shanked parts with various forms of head and parts with stepped shanks, while combinations of these two characteristics are also possible.

Specially designed presses for this process are now being developed by several manufacturers. There is an underdriven crank press built by Maypressenbau, on which the length of stroke and speed of extrusion are both variable. Open-sided toggle presses from the Maypress range are available in capacities from 30 to 100 tons, and are suitable for small ferrous components. Straight-sided toggle presses, with capacities from 160 to 1,200 tons, are suitable for producing heavier types of shallow components. For the pressures required to form very heavy components, of the order of about 1,000 tons/sq. in., hydraulic presses are desirable. Typical of this group of machines are the presses designed by the H.P.M. Co. and now built in this country by Cravens, Sheffield (Fig. 2).

It is true to say that wide interest has already been aroused in the possibilities of impact extrusion for steel products. The technique has already been applied extensively to armaments production in the U.S.A. and elsewhere, and the degree of interest already expressed points to a wide field of application in the automotive industries. Some of the components which seem particularly well suited to this method of manufacture are various types of power cylinders, gudgeon pins, needle bearing cups, bushings, pistons, fuel injection pump parts, special nuts and so on.

The majority of commercial steels can be cold worked to a greater or lesser degree in their fully annealed condition, but steels in the lower-carbon range are usually employed because in many instances these steels, after cold working, have shown equivalent physical characteristics to some higher-grade steels previously used.

The same basic principles apply as for non-ferrous materials, the essential differences being found in the method of blank or slug preparation, lubrication, tool design and pressures.

In general, the blanks are prepared from bar stock and may be cropped, sawn or parted off. The cropping method gives the greatest economy of material, but has one disadvantage in that the offcuts are usually slightly distorted and are subject to some localized work hardening. Thus the cropped blanks usually require a setting or sizing operation before extrusion. It might also be necessary for an annealing operation to be interposed, depending on the extent and amount of deformation in the sizing operation, or any preforming which might have been carried out simultaneously. Annealing is often essential when blanks are required which are thin in relation to their diameter, that is to say when a piece of bar of a smaller diameter is cropped off and then flattened to the required diameter and thickness.

Sometimes blanks of this type can be produced automatically from bar stock in cold heading machines, although there are usually some limitations as to the maximum sizes obtainable in this way.

However, it is true to say that the better and more accurate the blank, the better the final result. This is particularly true of cylindrical components where a high degree of concentricity of the bore with the outer wall is required. In almost all cases the blanks must be in a fully-annealed condition, and must be surface treated prior to extrusion to prevent metal-to-metal contact with the extrusion tools. The most commonly used surface treatment for steel is the application of a phosphate coating in combination with a lubricant, generally known as bonderizing or bonderlubing.

The importance of surface treatment of any material to be subjected to extrusion cannot be overstressed. It can make all the difference between success or failure. Breakdown of the protective coating will cause seizure between the metal of the workpiece and that of the extrusion tools, the consequent resistance to metal flow pushing up the pressure to a very dangerous extent, probably leading to tool failure.

The pressures required for steel extrusion are, of course, generally much higher than those for the non-ferrous group, and depend upon various factors, including lubrication, extrusion speed, and the degree of reduction or change in the cross-sectional area of the component.

Extrusion speed is subject to speculation and there are conflicting opinions at the present time. Speeds suggested vary widely from 10 to 30 in./sec. but, on the other hand a lot of successful extrusion work has been, and is still being, carried out at much lower extrusion speeds, particularly on heavy hydraulic presses. Higher speeds are probably more applicable to parts such as plain cylinders of constant wall thickness.

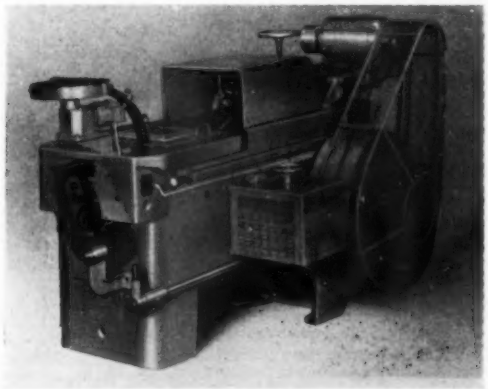


Fig. 1 *Herlan horizontal toggle-action extrusion press*

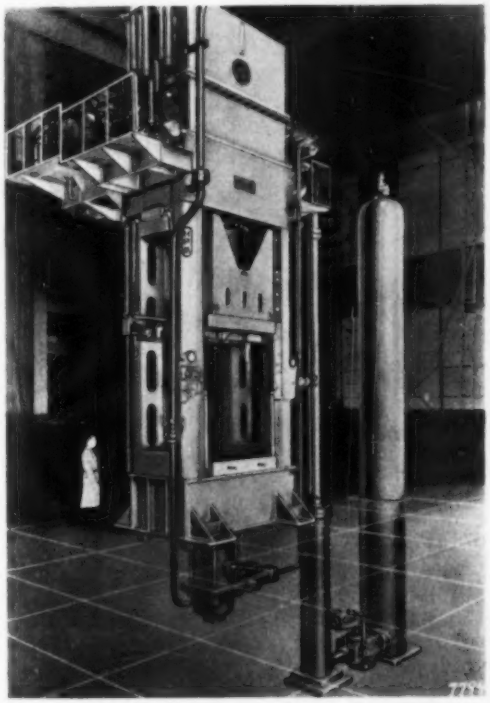


Fig. 2 *H.P.M. hydraulic extrusion press fitted with accumulator to give higher extrusion speeds*

Some claim that, for shallow or relatively thin parts, with changing cross-section and increasing area, very slow pressing is preferable because of the increased frictional resistance. The degree of reduction in area which can be obtained in one operation will depend largely on the characteristics of the material. Whereas with pure aluminium one can get reductions in the order of 99%, this is not practicable with steel even in the most favourable circumstances. The general concensus of expert opinion would indicate that for the best and consistent results the optimum lies somewhere between 55% and 70%. Greater reductions have been achieved in experiments, but do not appear to have been maintained under production conditions, as in such cases the specific pressure builds up enormously, causing premature failure or excessive wear on the tools.

Tooling is a vital factor with steel extrusion, and it is in this aspect of the process that tool design 'know-how' is important. Some parts may require several operations and the tool designer has to decide as to what can best be achieved at

each stage. He has to take into consideration the metal flow and tool loading, coupled with the choice and treatment of tool steel, not forgetting the question of ejection of the extruded parts. It is also essential that the tool designer should work in close collaboration with the designer of the components, as it is sometimes possible to effect slight modifications to the shape which, whilst in no way influencing the function of the component, can materially help in simplifying the extrusion operation. However, it is only by practical experience that this 'know-how' can be obtained.

Press Design

With regard to the actual presses for the cold extrusion of steel, one can say in general terms that almost any press will produce parts of a kind within its capacity. However, the design of the press is of greater significance than is generally realized. The prime essentials are rigidity, power, and some degree of speed control. Lateral rigidity is of equal importance to rigidity in the vertical plane. For example, with mechanical presses of the conventional over-crank type, good ram guides —which are essential—can be useless if the side frames flex under lateral thrust loads from the pitman or connecting head when the metal slug is impacted at a point well up from the bottom of the stroke.

Presses originally designed for drawing, stamping and forming operations do not generally measure up to the requirements for cold-flow pressing because they usually lack the essential rigidity and stiffness in the bed ram and side members, and also are frequently under-powered. This is reflected in the indifferent results obtained, pertaining particularly to inaccuracy of product, poor tool life, or low output rates.

Presses more specifically designed for this class of work are now becoming available, one example being the May under-drive press. On this machine the ram is actuated by twin connecting rods from eccentrics which are integral with the main gears. The point of connection with the ram is relatively low down, thereby reducing the tilting moment and lateral thrust on the guides. These presses can be equipped to have three different lengths of stroke and, as an example, the 300-ton machine can be equipped for strokes of 8 in., 10 in. and 12½ in. This, together with pole changing or variable-speed drive, can provide a wide range of extrusion speeds. The machine can operate at 20 to 30 strokes/min. and, if necessary, automatic feeds can be fitted to utilize these speeds to the full. A patented feature is a hydro-pneumatic shock absorber built into the ram which, it is claimed, permits higher extrusion speeds and is conducive to better tool life. Ejector gear, an essential item on any extrusion press, is also provided.

Another new class of machine now operating in the field is the horizontal multi-stage or transfer type of machine which, whilst largely intended originally for bolts and similar parts, is now finding application for a certain amount of extrusion work, or a combination of extrusion and upsetting work. These machines work direct from bar or wire stock, but to date are limited to relatively small parts.

With ferrous materials, applications in this country of a large-scale character appear to be limited to ordnance, to the manufacture of bolts of various kinds and to certain accessories in the automotive and cycle industries. The advantages of the process are material economy, greater strength of product because of better grain flow, reduction in the amount of pressing and machining work, leading to higher production and, generally speaking, better finish.

Future Trends

With regard to the scope for the future, one can expect in the non-ferrous group to see a wide range of copper and copper alloy parts such as pipe fittings, oxy-acetylene burner jet nozzles and other parts of various high-strength alloy steels, pure aluminium parts for such things as small pistons, bushes and a wide range of other industrial components.

In the ferrous group we shall see a wide range of parts for the motor car and cycle industries in particular. These will include a variety of special union nuts and bushings for fuel injection units, pistons, gears, shock absorber parts, power cylinders of various kinds, ball race and cycle head fittings, gudgeon pins and chain rollers, commutator bushings, shafts, etc.

Blast Furnaces for Zinc

IMPERIAL SMELTING CORPORATION is preparing plans for the installation at Swansea of its new blast-furnace process for the smelting of zinc or zinc associated with other metals. Unless general conditions show serious deterioration over the next few months, work on the site will begin at an early date, with a view to completion by the end of 1960.

The company's Avonmouth and Swansea Vale works are now the only producers of zinc and sulphuric acid in the country.

The Vale works, dating from 1876, was built and long operated by a local company. It is the only survivor of some four or five in the area, the remainder of which closed during the 1920s. It was in this period that the National Smelting Co. acquired it.

The company is to proceed at the same time with the plant of its process for the treatment of ferrous sulphate.

The result of the whole scheme will be a transformation in which hardly anything of the old process will remain. The new blast furnace scheme, which will increase present output considerably, will also carry further the improvement of atmospheric conditions in the works area.

View of the first two smelter bays at Baie Comeau

Production of Aluminium Ingots in Canada

New Smelter begins Operation

THE new aluminium smelter of the Canadian British Aluminium Co. at Baie Comeau in the Province of Quebec on the north shore of the St. Lawrence River, 400 miles north-east of Montreal, has recently begun production. One of Britain's most important investments in Canada in recent years, the company is a subsidiary of the British Aluminium Co. Ltd. and has been formed in partnership with one of Canada's largest pulp and paper companies; the Quebec North Shore Paper Co.

This event marked the completion of the first of four production stages of the £50-million plant which will eventually have an annual capacity of 160,000 long tons of virgin aluminium ingot. As an indication of the size of the smelter, this ultimate capacity represents two-thirds of the present annual consumption of virgin aluminium ingot in the U.K.

The short time required to bring the first stage into production makes the Baie Comeau smelter one of the fastest-built major projects on record. Work began on clearing and building access roads to the site in the severe Canadian winter conditions in 1956. A wharf capable of berthing three 10,000-ton ships has been built, with a belt conveyor system 3,000-ft. long to carry raw materials, such as petroleum coke and alumina, from the dockside to the smelter. At the same time, housing development has been undertaken, and a staff house, three blocks of apartments and over 200 houses have been built for the company staff. The staff living in the new township, which will ultimately include a church, a school, parks and a shopping centre, includes technicians from the British Aluminium Co. Ltd., mostly from the Highland Reduction Works in Scotland where aluminium was first produced on a commercial scale in the U.K., little more than 60 years ago.

The first stage of the smelter, with a capacity of 40,000 long tons a year, like the other three stages still to come, has two furnace bays each a third of a mile long.

Work on the second stage of the smelter is already well advanced and will be completed by the early spring of 1959, when the company will have a production capacity of 80,000 tons a year of virgin aluminium. Later, it is expected to go ahead with the two final stages.

Plant Layout and Handling

The two furnace rooms for Stage I of C.B.A.'s new smelter are more than 1,700-ft. long with a rectifier house at one end and a casting shop at the other. In addition, the plant comprises a carbon factory, laboratory, service building, workshops and offices, together with alumina and coke silos. Each furnace room has 84 furnaces of the

A New Refractory Material

An Example of Scientific Research

PROF. LOUIS LONGCHAMBON

The author describes the developments made quite recently in refractory cements, which were discovered more than one hundred years ago by Sainte-Claire Deville, a discovery which shows the possibilities of scientific research in a field which is generally left to empirical methods. This article, of which the first part appeared last month and the concluding part in this issue, is a slightly shortened version of a paper read at 'Journée des Réfractaires' held in Liège last year. The author is professor at the Faculté des Sciences de Nancy, and director of the Laboratoire des Réfractaires

Concluded from last month

SETTING and Hardening.—Hydration of calcium aluminates takes place with release of alumina and not of lime, as is the case with ordinary cements. Starting with mono-calcic aluminate and with two or three other aluminates, which we hesitate to recognize as constituents of hyper-aluminous cements, the hydration, from which hardening arises, is presumably due to the formation of a bicalcic aluminate with seven water molecules, according to Lafuma. Setting is normal, as it begins in the fourth hour of hydration. As for hardening, this is quick, as can be seen from the diagram in Fig. 2. This property, which is valuable in ordinary working, is no less so with refractory concretes, which can be used 24 hours after making. However, the speed of hardening is accompanied by a fairly intense release of heat, and this makes it necessary to sprinkle the concrete to prevent drying out.

Dehydration.—Fig. 3 shows how dehydration of aluminous cement appears when studied with the heat-balance. But the interesting fact technically is that this removal of water takes place without causing dislocation in the concretes, contrary to what happens with Portland cement.

Figs. 4 and 5 show the small changes in volume shown in refractory cements when they are heated for the first time. Swelling of the aggregates is compensated by contraction of the binder to such a degree that a cast concrete, for instance, shows less than two thousandths' expansion between 0° and 1,000°C. This property, joined to a certain porosity caused by the disappearance of water, probably explains the remarkable indifference of refractory concretes to heating shocks. In practice, furnace doors lined with cast concrete and chamotte can be put in position with the furnace working, without any precaution and, particularly, without any preliminary drying.

This unaffectedness to sudden heating is one of the primary advantages of refractory concretes. Only the huge monolithic constructions calling for tons of concrete require to be heated up progressively but still with much less trouble than is required for a construction in ordinary masonry.

Refractoriness of Concretes.—Figs. 6, 7, 8 and 9 are standard diagrams which show the deflection caused under a load of 2 kg./sq.cm. when the temperature is raised according to a given law. The vertical asymptote of these diagrams corresponds to the limit of practical utilization of the refractory material under test.

If we except the refractoriness of concretes in white corundum and Secar 250, which exceeds that of all industrial refractories, it must be recognized that the refractoriness of the concretes I have just mentioned is nothing extraordinary. In particular, concretes of cast cement and chamotte do not exceed 1,400°C., and those of Secar 250 chamotte, 1,550°C., these temperatures, which were found in the laboratory, having been confirmed in very numerous industrial applications. But in spite of these non-exceptional properties, the behaviour of these concretes itself is quite exceptional. Experience has shown the unforeseeable fact that a concrete made with crushed bricks shows itself to be very superior to these same bricks when new, although the properties of such a concrete are lower under laboratory tests than these same bricks. Very often when we have been

vertical stub Soderberg type, connected in series.

The 3,000-ft. belt conveyor handles at present about 125 tons of coke and alumina per hour and its capacity is designed so that this may be raised to 400 tons hourly. Substantial storage space is required owing to the period of closed navigation on the St. Lawrence, making it necessary to store materials for approximately a four-month period. The wharf, which has been in operation since its completion last September, has three 550-ft. berths which are capable of taking vessels up to 10,000 tons. The steel piles, which are 80 ft. long, are reputed to be amongst the largest ever rolled.

Carbon Plant

The aluminium production process requires about half a ton of carbon for every ton of metal produced. This is supplied at Baie Comeau from a carbon factory and the two main products are carbon paste for the anodes of the furnaces and carbon mixture for lining the furnaces.

Treatment of the calcined coke from its withdrawal from storage in two 6,000-ton silos involves drying in a rotary oil-fired dryer and its separation into various size fractions from ½ in. to dust by screens, the finer sizes being made as required by reducing any excess coarse materials first in roll crushers and subsequently in an air-swept ball mill. Predetermined quantities of each size fraction of coke are then blended and fed to the continuous mixers with molten pitch. The pitch is melted and all subsequent lines of the mixers kept hot by circulating hot hydrotherm fluid. The mix emerges from the continuous mixers as paste in 2½-in. strips which are cut in briquettes. The briquettes are cooled and stored ready for feeding to the anodes of the reduction furnaces.

The grist for the preparation of the furnace lining mixture is similar to that for anode grist but with calcined anthracite replacing the petroleum coke and the pitch for the binder being softened by creosote. Lining mixture is made in batch mixers.

The plant is designed so that close control can be exercised over its operation, and operating labour be reduced to the minimum by the centralization of all controls.

Power Requirements

The power for Stage I (120,000 h.p.) and part of Stage II is to be drawn from the nearby Manicouagan Power Co., which is owned 60% by Quebec North Shore Paper Co. and 40% by Canadian British Aluminium Co. Three new 50,000-h.p. generators have been installed, raising the total present capacity to 250,000 h.p. Quebec-Hydro, owned by the Province of Quebec, is building a large storage dam some miles up the Manicouagan River at Lake St. Anne, to provide a regulated water supply throughout the year for this expansion. Agreements between Quebec-Hydro and C.B.A. have been completed for the remainder of C.B.A.'s power requirements.

Power is transmitted from the Manicouagan Power Co. at 161,000 V. to C.B.A.'s outdoor switchyard, where the electrical supply to the smelter is transformed via 161,000-V. air-blast switchgear and 115-MVA. transformers, of English Electric Co. manufacture, down to 33,000 V. for the rectifying equipment for the furnace rooms and to 31,200 V. for the works distribution supply. The rectifying equipment for each furnace room comprises eight rectifier banks each consisting of 18 individual pumpless steel tank mercury arc rectifiers of British Thomson-Houston manufacture and delivers a total of 100,000 A. at 850 V. to furnace rooms.

Safety in Steelworks

FIRST issue of 'Safety,' a magazine of accident and health published by the British Iron and Steel Federation, made its appearance last month. To be published three times a year, it is intended to keep people in the industry continually aware of the need for safe and efficient working.

The 1957 accident frequency figures for the iron and steel industry suggest that one in 16 workers will have an accident in 1958. The improvement registered in recent years is being maintained—returns from 244 works for the third quarter of 1957 showed an average frequency rate of 2·60, representing a reduction of 8% on the corresponding quarter of 1956. But the number of lost-time accidents still totals 17,000 a year.

The new magazine is being published by the Accident Prevention Committee of the federation. It is intended to have a wide circulation in the industry to managers, foremen, safety officers, trade union officials, and members of joint safety committees in works. Twenty thousand copies of the first issue are being printed to allow for one for every 15 persons employed in the industry.

The Accident Prevention Committee of the federation was established in 1954 and has undertaken a considerable amount of work in collecting industry-wide statistics and conducting technical investigations, reports of which have been widely circulated in the industry. It has also encouraged accident research by the British Iron and Steel Research Association.

At a conference arranged by the committee in 1956, a great number of suggestions were made by the managers and works safety officers who were present and some 70% of these suggestions indicated that a widespread and regular interchange of information within the industry would prove to be one of the most effective means of reducing the rate of accidents.

It is for this reason that the committee has produced this new magazine, which is intended to appeal to all levels in the industry and will not therefore overlap with existing publications designed for specialists in the subject. It will contain feature articles, reports and reviews, correspondence, and information on a wide variety of subjects connected with accident prevention and industrial health. Future issues will not be confined to examples from the U.K. iron and steel industry, but will include references to the work of other countries and other industries, as well as to safety hazards in the home.

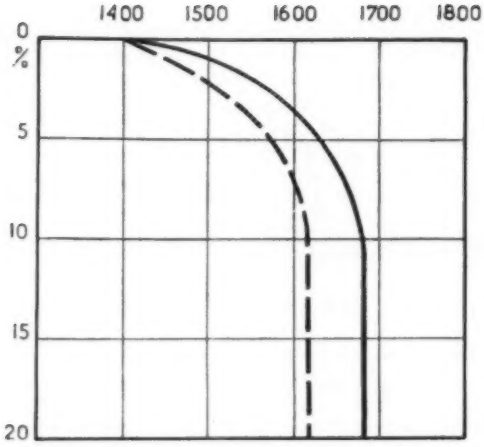


Fig. 6 *Distortion under load of 2 kg./sq.cm., chamotte 40-42% Al_2O_3*

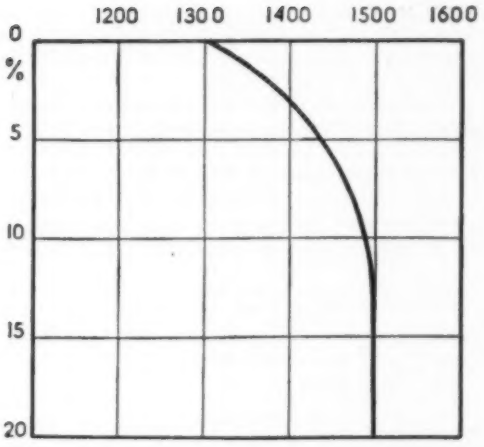


Fig. 8 *Distortion under load of 2 kg./sq.cm., magnesia*

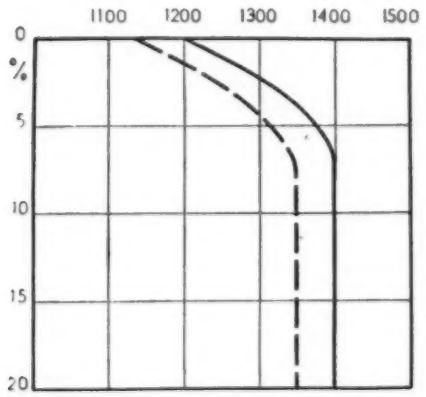


Fig. 7 *Distortion under load of 2 kg./sq.cm., brown corundum*

In the above figures the bold line represents Secar 250 mortar, and the dotted line cast mortar

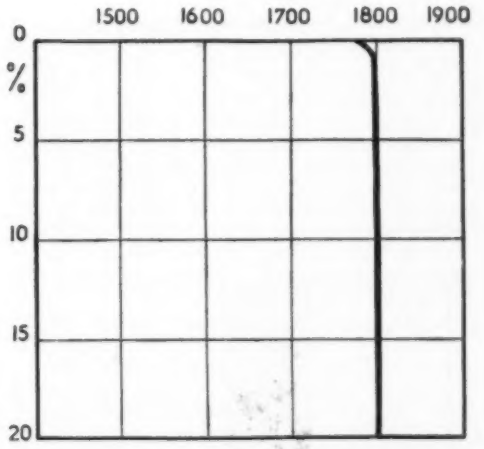


Fig. 9 *Distortion under load of 2 kg./sq.cm., white corundum*

of K = 0·7. It is of the order of that of silico-aluminous bricks, which varies from 0·4 to 1 according to technique of manufacture. Corundum-Secar concretes are remarkable for a conductivity nearly twice as great, which enables them to release, for equal thickness, many more calories. Consequently, in extreme cases, they suffer much less from excess temperatures in the furnace. This fact is found with industrial furnaces running at very high temperatures. When the lining is so worn as to be only 5 to 6 cm. thick (2 to $2\frac{3}{8}$ in.), the lining is extremely durable provided that the outer sheet is cooled. Benefit is thus gained from the extreme refractoriness and the great conductivity of these concretes.

Inversely, concretes can be made up with a very low coefficient of conductivity by using, as aggregate, materials which are both insulating and refractory, such as diatomite or vermiculite. A vermiculite concrete easily reaches a coefficient of 0·2, that is to say of the order of the best insulating refractory bricks. As we shall see later on, it is easy to obtain composite concretes by pouring into one mould two portions separated by a sheet, one of refractory

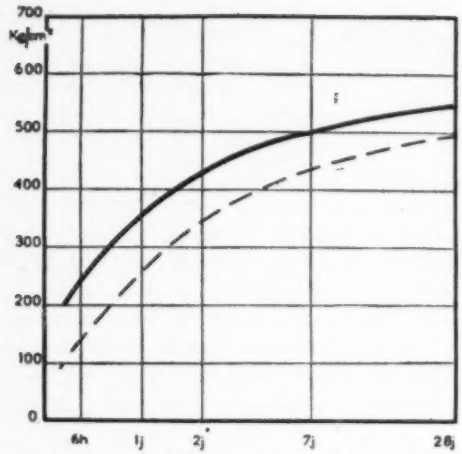


Fig. 2 *Cold hardening of Secar* 250 (*dotted line = concrete, bold line = mortar*)

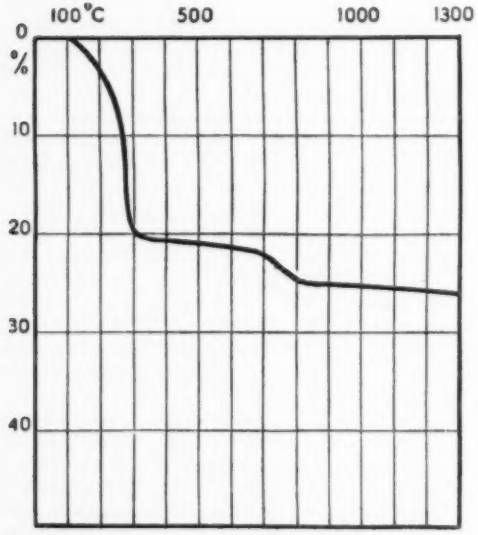


Fig. 3 *Weight loss of pure Secar* 250

called to a furnace mishap causing a loss of excellent refractories we have restored the position by crushing these same refractories and building a monolithic block with a basis of cast cement or Secar 250, paradoxical indeed as this may seem.

This indisputable state of affairs makes evident what I call the virtue of monolithism. This is explained after it has happened, in part at least, if we remember that brick structures often perish at the joints in the bricks. The monolithic structure

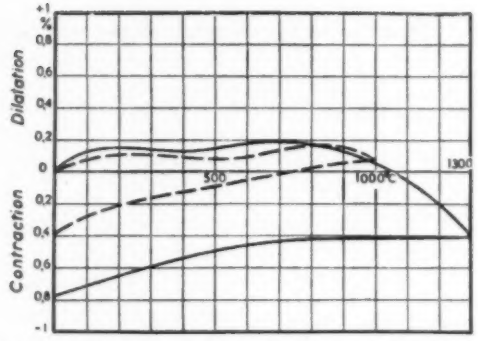


Fig. 4 *Changes in volume (bold line = Secar* 250, *dotted line = cast mortar, chamotte* 40-42% Al_2O_3)

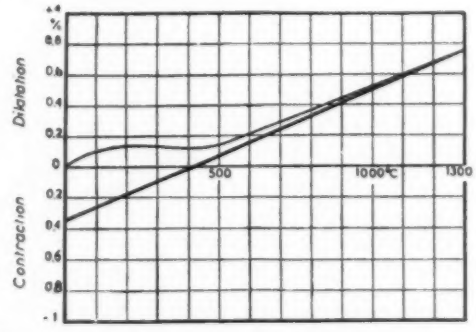


Fig. 5 *Changes in volume, Secar* 250 *corundum*

not having any joints offers a regular surface against corrosion. Moreover, the fact can also be invoked that local overheating disperses better in the mass of a monolith than in brick masonry.

Cement Contents.—The curves given in Fig. 10 have been drawn up in the following way: all the lines relate to concretes of Secar 250, but each curve corresponds to a particular aggregate. Also the deflection diagrams have been drawn for each aggregate with varying amounts of cement and on each of the diagrams the temperature of deflection has been taken as that for a deflection of 10%, this being regarded as the limit of use.

The curves on Fig. 10 show variations in this limit of use as a function of the cement content. In practice these contents come between 300 and 500 kg./cu.m. It will be seen that, within these limits, the cement content has little effect on chamotte concretes, but it has an appreciable influence on corundum concretes, in agreement with the alumina-limestone diagram.

Heat Conductivity.—The heat conductivity (Fig. 11) of chamotte and Secar 250 concretes has a value

Granulometric Composition of Aggregates.—Crushed material should not be taken as it comes but should be graded by screening into different grain sizes which, in practice, are as follows:—

Grains from 0 to 1 mm.
1 5
5 10
5 20
10 30

The largest grains for a given job must have a thickness of from one-fifth to one-tenth of the minimum thickness of the product. The size must not exceed 30 mm. (1¼ in.) dia., even if blocks of more than 500 mm. (20 in.) thickness are being cast, which is an exceptional case.

The five examples in Table III correspond closely to all possible cases. In the first column are given the volumes in litres of each category of grain to use 50 kg. (1 cwt.) of cement. In the second column is given the volume, in arbitrary units, for each grain and for the cement.

TABLE III *Examples of grain sizes for articles of different thicknesses*

Thickness of articles	Constituents	Col. 1	Col. 2
Mortar or very thin articles	0 to 1 mm. grains	65 l.	7 vol.
	Cement	50 kg.	4 vol.
From 20 to 50 mm.	0 to 1 mm. grains	45 l.	9 vol.
	1 ,, 5 ,,	55 l.	11 vol.
	Cement	50 kg.	7 vol.
From 50 to 100 mm.	0 to 1 mm. grains	50 l.	10 vol.
	1 ,, 5 ,,	60 l.	12 vol.
	5 ,, 10 ,,	45 l.	9 vol.
	Cement	50 kg.	7 vol.
From 100 to 200 mm.	0 to 1 mm. grains	40 l.	8 vol.
	1 ,, 5 ,,	45 l.	9 vol.
	5 ,, 20 ,,	85 l.	17 vol.
	Cement	50 kg.	7 vol.
Above 200 mm.	0 to 1 mm. grains	40 l.	8 vol.
	1 ,, 10 ,,	75 l.	15 vol.
	10 ,, 30 ,,	85 l.	17 vol.
	Cement	50 kg.	7 vol.

Applications

The examples I am going to give can be grouped into two main classes, according to whether the parts to be made are of the shape which it is usual to make with the ordinary materials, or whether it is intended to make monolithic blocks which are the typical field of concrete.

Shaped Articles.—These include laboratory equipment, such as crucibles of various sizes. The very small crucibles can be made by casting in metallic moulds, in which case setting is assured by immersing the moulds at the beginning of the fifth hour after the concrete has been put in. Another article is an electric muffle furnace, cast in one piece with grooves cast in for the heating elements. This illustrates the fact that refractory concretes are exceptionally useful for science and works laboratories. Indeed they are the only materials to make any shape required without delay in any kind of refractory. They also allow of modifications and repairs being made, which would not be possible with other kinds of products.

In the making of very large castings, the method is a very simple one. One workman prepares the mix and another puts it into the mould, which is oiled before being used. A pneumatic lance is used to stir up the concrete mass to ensure uniform density. After preparation the mould is covered with sacks and is watered after four hours to avoid heating up. Blocks of 2 tons weight are made in this way.

Burner Nozzles.—This is another good application, as the masonry of boilers, heated with mazout, wears away very quickly by contact with flames. Steps have had to be taken to allow of easy replacement of worn portions, and nozzles have been devised which fit into the walls and are easily interchangeable. Experience has proved that burner nozzles made of 'fondu-corundum' or 'Secar-corundum' give much greater resistance than usual refractories and it can be said that burner nozzles are now really a speciality of refractory cement. These nozzles range in size from the smallest to the largest and are made in one piece or in two.

A wide variety of parts can be made with one section in dense refractory material and another in light insulating material. Vermicular cast concrete is used for insulation, whilst the refractory material can be of any composition desired. Monolithic structures can be made in this way.

Brick Kilns.—The making of brick-burning kilns, either with chambers, or of the tunnel type, is one of the outstanding successes of refractory cement. The Hoffman type of kiln, for instance, is made with monolithic concrete, the roof being in vibrated concrete. In some cases, concrete is used to replace the original brick roof, when repairs are necessary. In one instance quoted, part of the old brick roof over one of the doors was repaired in concrete without the kiln stopping work.

Tunnel Furnaces.—Refractory concrete is used for the roof of mazout combustion chambers, as well as for slab supports for bricks or ceramic products in tunnel furnaces.

Lime Kilns.—As is the case in blast furnaces, efforts are being made with lime kilns to put in refractory linings which are denser and increasingly rich in alumina. The result is not particularly good because, as soon as there is a heat flash on the lining, the refractories combine with the lime

concrete and the other of insulating concrete. Immediately after casting the sheet is withdrawn and the two parts set at the same time, thus forming one single block.

Melting Point.—Table I shows the melting points of the most widely used concretes.

Use of Road-making Materials

When we speak of refractories we immediately think of refractory-clay bricks of silica or magnesia. It is forgotten that previously there was no specialized industry for refractory materials and that blocks for making furnaces were cut directly from rocks. Open-hearth furnace roofs as well as linings of lime kilns were cut from quartzite or from grit, without any special industrial treatment. I do not intend to deny the very great progress which the refractory industry has made since those days, but this industry has gone far beyond what is necessary when dealing with temperatures below 1,200°C., these being the temperatures which concern the greatest part of refractory constructions.

TABLE I *Melting points of common concretes*

	°C.
Fondu Lafarge	1,310
Fondu Lafarge/chamotte 40-42	1,540
Secar 250	1,660
Secar 250/chamotte 40-42	1,640
Fondu Lafarge/brown corundum	1,700
Secar 250/chromite	1,760
Secar 250/magnesia	1,770
Secar 250/brown corundum	1,800
Secar 250/white corundum	1,860
Secar 250/SiC	1,940

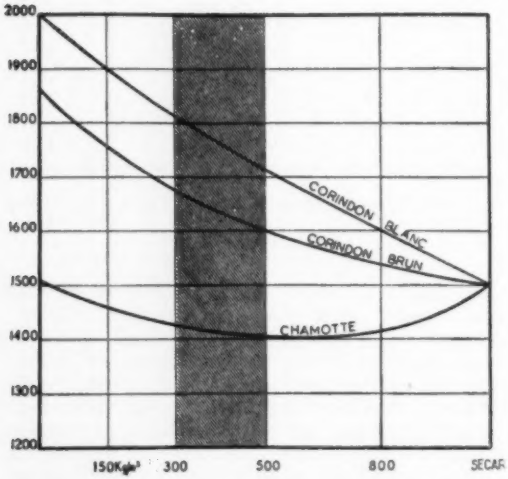


Fig. 10 *Effect of cement content on limits of use. Temperatures are for a 10% deflection under load of 2 kg./sq.cm.*

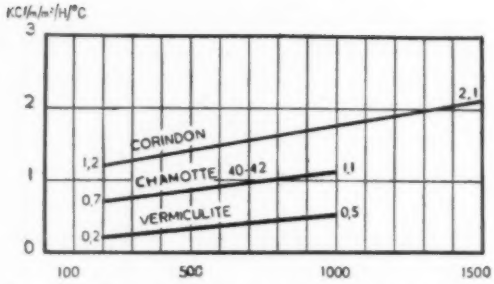


Fig. 11 *Heat conductivity. Secar 250 mortars*

It is quite unnecessary to consider special refractory material for temperatures below 1,200°C. Cast concretes with aggregates made of stone materials for road making are perfectly satisfactory, provided these materials are neither calcareous nor gypseous. Trap rock in the eastern region, schists in the west and south-east, lavas and pozzolanas in the centre of France are excellent refractory materials, and also insulating in the case of the pozzolanas up to 1,100 to 1,200°C. From the point of view of the national economy, we thus avoid wasting those refractory clays of which the deposits are not unlimited, and of which the plastic properties, irreplaceable in other uses, are of no use in the refractory field.

Table II specifies the range of temperatures for which can be used the various natural or synthetic products used as aggregates for ' Fondu ' or Secar 250 concretes.

TABLE II *Temperatures at which products may be used in concretes*

Temperature, °C.	Fondu Lafarge	Secar 250
800	Red bricks, rock, slag, refractory scrap	
1,150	Basalt, trapp, schists, silico-aluminous, quartzite	
1,200	Baked brick 25-30 (chamotte)	
1,350	Chamotte 40-42	Chamotte 40-42
1,400	Mullite, sillimanite	
1,500	Magnesia, chromite	Magnesia, chromite
1,600	Corundum	Sillimanite, carborundum
1,800		Silica, corundum

Locomotive Arches.—The engineers of S.N.C.F. have solved the problem of loco-furnace arches by definitely substituting monolithic arches to replace brick arches, which were of the traditional type made of silico-aluminous bricks. In the 150 P type of locomotive their life was 17,000 km., but with the same arches remade in cast concrete, with the same worn bricks crushed down as aggregate, the life exceeded 70,000 km. It is calculated that the cost of these arches in concrete spread over total life is not more than one-third of the former types. Moreover, brick arches sometimes collapsed owing to sudden changes in draught, whereas no such accident has yet occurred with concrete.

Furnaces for Roasting Pyrites.—This type of furnace seems to be a definite victory for refractory cement. In a furnace 10 m. high (32½ ft.) and 6 m. (19 ft. 6 in.) dia., the nine floors were made of eight monolithic segments cast one alongside the next, with a 5-mm. (¼-in.) joint on the periphery narrowing to 0 at the centre.

Conclusions

The advantages of refractory cements are advantages in supplying and putting to work, and technical advantages in use.

In the usual method of manufacture of a furnace it is necessary to design the furnace well in advance and divide it up into elements which will be standard bricks or shaped pieces. The smallest job calls for 50 to 100 different shapes and for each of them a special mould must be made. Consequently, not only will these special shapes cost a great deal but they will also take a very long time to produce.

In the matter of delivery, the supply of refractory cements presents the greatest simplicity. Aggregates are supplied in bulk to the size required, and no difficulty is to be expected in the supply of the cement. It is certain that no part of whatever shape will be lacking and there is no need even to consider such a possibility.

Refractory Materials of the Future

The preceding account has been given as an illustration of scientific research. The discovery of a savant, long since forgotten, brought to perfection by 20 years of patient work by a band of technicians, has given the heating industry an entirely new method of building furnaces and covering a wide range of materials. Whether it is a matter of cost price, of speed of construction, of simplification of supplies, or of life in service, this new technique replaces and surpasses the traditional method of construction in more than 80% of cases.

I should like to insist on the idea that progress in refractory matters cannot come from the refractory industry itself but must come from research carried out by the users or by the research organizations in immediate contact with technical requirements.

If, during the last 30 years, I have been able to bring about some improvements in refractory materials and to make some advantageous substitutions, it has only been possible to do this by studying on the spot the conditions in which a given material suffers attack by heat, gases, dust, magmas, and thermal or mechanical shocks. The transfer of these conditions to the laboratory is the second phase in this investigation and, incidentally, the more difficult, since it is impossible in fact to reproduce them exactly. We are therefore compelled to study each factor of disintegration by itself and make a synthesis of them, bearing in mind the seriousness of each one. It frequently happens that the best solution, or the least bad one, is found in a compromise, in which all the physical and chemical properties of the material are not used to their maximum. To take a very simple example, porosity, harmful to chemical resistance, is helpful in resisting heat shocks to such a degree that an average porosity will sometimes be preferable to a very dense product, although this is generally being sought for.

The transfer of the problem to the laboratory only gives a qualitative information on the direction in which the characteristics of the product should be evolved. This orientation must be controlled by an immediate return to actual practice and it is by alternating between laboratory and reality over a long period that progress is made in this very thankless field.

Glassmakers are the only ones in the heating industry who have realized that they could not leave to others the task of improving refractories in contact with glass, and of which the quality is one of the essential conditions for getting a good product.

Such is the example given by an industry for which refractory material was vital. It should be followed by other heating industries which have suffered, up to now, from the limitations imposed by the nature of the refractory materials available, and which must set themselves free from them before progress can be made. But we must not hide from ourselves that this matter must be taken up from the starting point of fundamental science. Empiricism has given all that could be expected of it; knowledge, as applied to natural minerals, has also nearly reached its limit. To do something new, to make a worth-while step forward, either in materials or in techniques, we must, by all the evidence, advance into the unknown. It is essential that mineralogical chemistry, aided by the newborn nuclear science, should make as much progress as did organic chemistry during the last half-century. The thing is possible; it is sufficient that we wish to do it and to pay the price for it.

producing a very meltable calcic glass. The lining is pierced and the bricks above this hole come down gradually with the burden, thus leading to the loss of the lining. Construction of a lime kiln in concrete with monolithic courses makes it certain that, even if there is piercing of the lining, this destruction will not lead to the loss of the whole lining. It can always be repaired by applying concrete after simply chipping out the affected portion.

Tests carried out in the refractories laboratory of the University of Nancy allow us to think that corundum or magnesia concretes would fully replace chamotte concretes for lime-kiln combustion zones, but these tests have not been confirmed on the industrial scale. Several monolithic linings in cast cement and chamottes have been successfully installed in fatty-lime kilns to the complete satisfaction of the industrialists who took the initiative in this matter.

Metallurgy.—The metallurgical industry makes use of two kinds of refractories—those which are in contact with hot gases only, and those which are in contact with molten slags or with molten metal.

In the first case, all that is required from the refractories is refractory qualities, and concrete is suitable in all cases by adapting composition to working temperature. In the second case, things are quite different. Henri Sainte-Claire Deville insisted on the fact that calcium-aluminate is not attacked by aluminium nor by alumina. Similarly for zinc and lead. A modern instance, 100 years afterwards, of the Sainte-Claire Deville furnace, is an induction furnace in Secar-corundum for melting aluminium.

The iron and steel industry has not yet undertaken systematic tests. Those which are in hand at my laboratory have dealt up to the present with linings for high-frequency induction furnaces for steel melting, either basic, acid or neutral, all of which have given full satisfaction. It would in any case be useless to claim that concretes, in spite of the variety of them which can be made, have a universal polyvalency. There is no doubt, however, that certain materials, such as magnesia or silica bricks, which have been developed by the refractory industry to a state of perfection only limited by the natural origin of the raw materials, retain their superiority in the special fields for which they have been created.

Electric Furnace Doors.—Doors of furnaces for making stainless alloy steels have been produced in Secar/corundum, with full success both as regards length of life and cost price.

Semi-permeable Linings.—If the fines of corundum are left out of Secar/corundum concrete, for instance, a product is obtained which is permeable to gas. A lining so produced allows of gas being injected, oxygen for example, or air, through a mass of molten steel. It can be seen what can be the applications to which such semi-permeable materials can be put in converters and for the new techniques of oxygen refining.

Stamping Furnaces.—Burner nozzles for mazout fuel are being made in Secar/corundum for stamping furnaces, that is furnaces for reheating round steel bars for stamping into bolts or rivets. This concrete has particularly good resistance both to high temperature and to sudden variations of temperature on lighting and damping down.

Annealing Furnaces.—Monolithic plates in concrete are used for combined conveyor doors of furnaces for annealing malleable cast-iron pieces placed in piled-up stills for annealing at 950°C. Fire-bridge pack walls are being made partly from fondu/corundum; the burner flames attack these pack walls direct at the foot of the cylinders. The excellent conductivity of the fondu-corundum mix has enabled 24 hours to be gained on the seven days which this operation took when the walls were made of brick.

Salt Quenching-furnaces.—Concrete of cast/chamotte, cast/corundum, or Secar/corundum, if all traces of iron have to be removed, are perfectly satisfactory for these furnaces.

Soaking Pits.—Refractory concrete is the material to choose for all furnaces for annealing, reheating or slow cooling. With a suitable choice of aggregate and size of same, the furnace walls are given the desired conductivity. A battery of soaking pits can be made in one unit, and these give a long life.

Coke Furnaces.—The use of concrete for lining coke-oven doors is now standard practice. Relining can be done in the vertical position by using a sheet metal mould. After two years' service such concrete linings are in very good condition. Also, monolithic linings are used for metal chimneys through which gases are discharged during loading and unloading of the ovens. These linings are subjected to great changes of temperature, but, after five years' service, they have been found to be intact.

Recuperators.—Refractory concrete is perfectly suitable for making recuperators. They can be given a conductivity and a density very much higher than those of ordinary materials, and this assures a considerable greater heat exchange value per cubic metre of the recuperator.

For demonstration purposes I built, in 1938, at the refractory laboratory of the University of Nancy, a monolithic recuperator of a total weight of 13 tons. This had two alternating recuperator chambers heated by a coal hearth. This test of huge monolithic masses, 13 tons, presenting very complex architectural problems, has not been followed as yet by such daring industrial applications.

the recrystallization of alpha-iron has been studied. With small reduction in rolling, large grains appeared below the surface. With greater reduction, the reverse was observed in that the large grains were at the centre of the sheet. At still higher reductions the recrystallized structure became uniform. Temper-rolling and uni-tempering processes were also studied by this method. The temperature range, from the beginning of recrystallization at the edge of the sheet to the end of recrystallization in other parts of the sheet, was assumed to be a measure of the variation of cold-work through the section. This range of temperature was 50°F. and 140°F. for samples elongated 7% by the uni-temper and temper-rolling process, respectively. It has also been shown that in drawn brass wire and rolled brass sheet recrystallization commences preferentially in two zones: first, at the surface of the wire or sheet as a result of additional deformation due to frictional forces and, secondly, in a zone intermediate between the surface and the centre. In rolling, the surface effect persisted to some extent up to 50% reduction. Above this value the sheet was uniform throughout its thickness.

Mechanical Properties

Tensile strength has been used to study inhomogeneous deformation in hard-drawn copper wire, the method consisting of removing the outer layers of metal by solution in acid. Wires were etched for different lengths of time and the tensile strength determined. From these values, the strength of the portions successively removed was computed by a simple process of subtraction. It was shown that annealed copper wire given a small reduction had a surface layer of high tensile strength and a further zone of high strength between the surface and centre. With greater reductions the region of high strength was found midway between the surface and the centre of the wire. It has been shown that in drawn bars the coefficient of anistropy measured on tensile specimens varies in a continuous manner from one surface of the plate to the other, and that the tensile strength of brass wire is raised by an increase in the angle of the drawing die, the greater strength being due to increased inhomogeneity in specimens drawn through the high-angle die. For the same percentage reduction the surface hardness of drawn copper specimens was much higher than the centre, while the reverse was true for rolled specimens.

X-ray Methods

Many authors have observed that X-ray patterns are different at the surface and at the centre of specimens given standard cold-work treatments. Diffraction patterns of copper wire obtained after etching off increasing amounts of material show a change from random orientation on the outer surface to oriented condition as the centre of the wire was approached. It has also been observed that the nature and extent of preferred orientation varies from surface to centre of a drawn wire and somewhat similar conditions exist in cold rolled products. Under a moderate degree of cold deformation, different degrees of disturbance of the crystal structure were found to obtain at different depths in test rod. A larger amount of cold deformation brought about homogeneity of the heterogeneous crystal air structure.

In general, body-centred cubic metals such as iron have a simple texture at their centre after deformation by rolling, swaging or drawing. The outer layers, however, with almost any type of deformation, contain orientations not found in the centre. Mild-steel sheet reduced 85% by cold-rolling was found to have at the surface a differently orientated texture from that of the interior. The origin of this difference might come from frictional and geometrical effects, states the author. Consequently, surface textures are probably affected by factors such as ratio of roll diameter to sheet thickness, reduction per pass and so on. However, preferred orientations are not produced for small amounts of deformation. As yet, little work has been done to determine any differences in X-ray patterns of the surface and centre structure of lightly deformed metals such as temper-rolled steel.

Tensile Deformation

Straining in tension was for a long time thought to produce a homogeneous deformation. This is not always true, since it has been shown that a strong surface effect was operative in coarse-grained polycrystalline lead, leading to a 'size effect.' Previous evidence of this was disclosed in studies of the surface-layer-tested solid round bars and thin tubes of the same material made by drilling the inside of the former. The tubes were 1¼ in. i.d. and 0·006 and 0·015 in. wall thickness. The yield stress attained by the thinnest tube was little more than half that of a solid specimen and the character of the yield was entirely different corresponding more closely to that which would be expected from iron single crystals. Subsequent microscopic examination revealed that the crystal size and wall thickness were of the same order of magnitude.

When the grain size is small compared with the smallest dimension of the specimen, another phenomenon is also operative, X-ray evidence showing that, for tensile loading, the stress in the surface layer is less than in the interior of the crystal. The same observation was made on tensile, compression and bend test specimens of steel and aluminium. The most likely explanation was that the layers

Study of Metal-working Processes

Inhomogeneous Deformation of Material

A COMPREHENSIVE survey of available methods of studying inhomogeneous deformation in metals covering many years has been compiled by H. P. Tardif, physical metallurgist, Canadian Armament Research and Development Establishment. The author covers various aspects of the subject including marker methods to determine inhomogeneous forging structures, effects of recrystallization, influence of mechanical properties, X-ray methods, tensile deformation and microstructural studies. The following extracts are mainly confined to work carried out during the post-war period.

When all particles in a forged sample are strained by the same amount and follow similar paths, the piece is said to be homogeneous. These conditions obtain on a macroscopic scale in tensile deformation, at least up to the necking point. However, in metal-working processes, due to certain shearing and forging effects and to friction between the fact of the working tool and the metal being worked, the conditions for homogeneous deformation are not present and the deformation is inhomogeneous. A large amount of work has been done to reveal the presence of this condition.

Marker Methods for Forging Structures

Marker methods of studying forging structures include all systems which enable the path of particles at various points in the specimens to be followed. They include the use of reference grids at the surface of a specimen or at the interface of composite specimens, the use of markers as plugs, composite billets of dissimilar material and combinations of these methods.

Reference networks for determining ferro formation are in the form of rectangular or polar grids, ruled or scribed or transferred on the specimen by various photographic or similar means. The deformation of the grid is noted after deformation of the specimen. Another method of flow determination is that in which holes are drilled in the metal and plugs of the same diameter inserted. It was found that during rolling the vertical plugs become curved in the direction opposite to that of the movement of the bar, this indicating a movement of the material in the inner zone of the bar in a backward direction relative to the surface. Screws can be used to show the degree of compression at various heights by the changes in their pitch. Compressive strain has also been determined by inserting small plugs at close intervals in a block of steel. Circular plugs inserted horizontally, at right-angles to the direction of rolling, are deformed into an elliptical shape, the major axis lying in the direction of rolling. Experiments made on brass, nickel and on oxidized and non-oxidized copper billets have shown that the principal factor determining the type of flow is the degree to which the skin of the billet remains in place against the container wall. In some experiments radioactive plugs have been placed in holes and after deformation the pattern of flow detected by Geiger counter techniques. The method of inserting plugs can be criticized on the grounds that, even if the material of the plug is identical to that of the bar, it is not part of the bar and may not therefore deform in the same fashion as the original material might have done.

Observations in hot rolling show that, with the same total reduction, repeated passes seem to cause a greater advance of the outer zone of a sheet than a single pass. Thus the shape of the front of mild-steel strip during cold rolling has been found to be dependent on the draft, it being concave for very light cold reductions and convex for heavy cold reductions. The same method has been applied to the rolling of bars and to wire drawing. The distribution of strains within a bar were determined by radiography after 20% rolling reduction, a lead grid having been embedded in a cast tin bar. Lateral strain changed from tension at the centre of the bar to compression midway between the centre and the outside in a section perpendicular to the roll axis. This and similar methods are said to have all the advantages of the previous methods without the disadvantage of the lack of adhesion between the different parts of the sample.

Recrystallization and Deformation

It is well known that increased cold work depresses the recrystallization temperature. Therefore it was postulated that, if the deformation was not uniform throughout the specimen, then, on annealing, the portions more heavily worked would recrystallize at a lower temperature than the rest of the specimen. Using this method, investigators have observed that alpha-iron recrystallized more easily when deformed in compression than when deformed in tension. The effect of type of deformation, such as torsion, elongation and rolling, on

nearest the free surface of the specimen start to yield under a lower stress than those at the interior of the crystal because the former are not constrained by being completely surrounded by other grains. This stress can be as low as one-half or one-third that for uniform yielding. The depth of this surface effect would be 0·04 in. for small strains. A macroscopically stressed surface layer 0·01 in. deep on Armco iron and steel in tension had been observed, being ascribed to the fact that the yield strength of grains with a free surface is lower than that of grains in the interior of the aggregate.

The author comments that, although this effect is of no importance on the overall strength of large specimens, it is present and may cause trouble in certain cases such as growing single crystals. Many investigators have found that, when using the strain-anneal method for this purpose, the crystals produced were often covered by a thin layer of fine crystals. Since the amount of strain required to induce grain growth to such an extent as to produce a single crystal is critical, it is thought that the lower internal energy of the surface layer will fail to induce rapid crystal growth. An increase of 50°F. in the annealing temperature near the end of the treatment ordinarily will prevent the formation of this layer of fine crystals, this being in accordance with the observed fact that the lower the strain the higher the annealing temperature must be to obtain large crystals.

Microstructural Studies

Discussing micro-inhomogeneities, the author recalls that, from the plasticity point of view, metals were considered to be isotropic in such studies. Actually, this isotropic medium is made up of anisotropic crystals and is isotropic by compensation only. The manner of grain deformation and the extent of influence of grain boundaries is a much more complex problem of great importance. Regarding pure metals and single-phase alloys, the mode of deformation of individual grains in polycrystalline aggregate was studied very clearly, it being observed over 40 years ago that, during tensile deformation of coarse-grained aluminium, the deformation at the boundary was much less than in the centre of the crystals. This effect was noticeable at a distance of 0·25 in. from the boundary than at the centre of a crystal and it was concluded that the extent of deformation was correspondingly smaller near the boundary. It has since been pointed out that this conclusion does not seem to be justified, since deformation due to the multiple slip gives rise to a smaller change in orientation than the same deformation due to single slip. In general, it has been found that elongation at the boundary was smaller than that of the adjacent crystals. The interaction between crystals must be dependent on their respective orientations.

In an investigation into the geometry of plastic deformation in the interior of a polycrystalline aggregate by means of a grain-counting and measuring technique, longitudinal and transverse counts were made before and after deformation. From the length and width of the grains the average strain suffered by them could be determined. In certain cases, the average strain was less than the overall aggregate strain and the difference was attributed to relative grain movements. The effect of rate and temperature of deformation on relative grain translations could therefore be determined. Thus with slow deformation at 350°C., surface grains of an aggregate deformed 50% by elongation exhibit a 40% strain, while interior grains exhibit only 6%. The elongation and microhardness within the grains of a deformed polycrystalline aggregate of aluminium were found to vary considerably, being influenced by the deformation or orientation of neighbouring grains. The percentage elongation within grains varied from 2·7 to 13·7% compared with the 5% original deformation. The same wide variation in elongation was found when employing a fine grid photographically reproduced on a large grain specimen of aluminium. The elongation was generally restricted in the vicinity of grain boundaries and the form of the restriction appeared to depend on the orientation relationship between neighbouring grains.

X-ray methods have shown that lattice distortion and fragmentation occur to a greater extent at the boundary than at the centre of a crystal. Even in stretching single crystals of aluminium, asterism appeared in X-ray photographs after 4% deformation, this showing that plastic deformation of crystals by slip is not merely a simple geometrical translation of parts of the crystal along the slip plane, but involves local changes of orientation and possibly fragmentation. With cadmium single crystals a larger extension was obtained without asterism, but the slightest bending of the specimen produced this condition. Evidence supports the view that, when deformation takes place by pure gliding on the slip plan, no asterism is present, but that inhomogeneities such as deformation bands and kinking will generally show asterism. These inhomogeneities arise as a result of the nature of the dislocation. Reference is made to further work confirming the inhomogeneity of deformation of grains in an aggregate. Naturally, at high or low extremes of temperature and rates of straining, this problem becomes more complex because of phenomena such as cell formation, recrystallization, ageing and precipitation. It has been shown that during deformation large changes occur in certain interatomic distances in the cementite and that part of the particles dissolve to relieve the stresses. Attempts

are being made to explain these phenomena on the basis of dislocation theory.

In two-phase alloys the effect of embedded particles on the flow of metals during deformation is of great importance. The particles may be harder or softer than the matrix and consequently additional plastic flow must take place in the vicinity of the second-phase particles.

Conclusions

In the course of his conclusions the author states that work on the subject of plasticity of metals is progressing in two main directions. In the first case, the mathematical approach is used to determine the geometry of the flow of metal in relation to the stress system. The solution is obtained by means of a slip-line field determined by a process of trial and error. Many simplifying assumptions are made, such as perfectly plastic material deformed under conditions of plane strain. Moreover, these theories do not take into account the atomic 'texture' of the 'plastic medium.' An idea of the shape of the slip-line field may be obtained by means of the simulative distortion of scribed networks of lines on sectioned specimens. This and similar techniques can be of great help to workers in this field.

The second approach is that of the metal physicists who ultimately wish to predict the plastic properties of metals on the basis of their atomic structure. The yield criterion has first to be solved for the different space lattices, and later other effects such as strain-hardening, grain boundary interaction and other factors will be taken into account. A large amount of work is being done along these lines but full understanding of deformation on the atomic scale has yet to be achieved.

A difficult problem is the correlation of results produced by these two different approaches to the subject. During rolling, for example, the relative movement of the elements making up the strip has yet to be related in a simple manner with the work-hardening of these elements. It is observed that, in mechanical working processes, strain hardening is generally greater than that obtained in a tensile test and this is ascribed to inhomogeneous deformation on a macro-scale. From an engineering point of view, one unifying factor in the studies of inhomogeneities of plastic deformation produced in metal-working processes might well be the coefficient of friction. The frictional conditions between slab and rolls, billet and container, wire and die, affect both the force required and the pattern of flow. Study of frictional conditions during these processes is a step toward the elimination of inhomogeneous deformation and the obtaining of better products.

Institute of Metals

Concluded from page 96

for this practice is that specifications are liberal and the two most important specifications allow up to 0·75% impurities to be present, apart from lead, which is one of the main constituents. It is essential to control tin to less than 0·2% and antimony to less than 0·01% with bismuth of, say, 0·005% max. The alpha-beta brasses seem less sensitive to bismuth than any of the other copper alloys or copper itself which is most adversely affected by bismuth. Antimony in amounts of more than 0·015% markedly reduces ductility and impact strength.

In the fire refining of copper, there are possibilities of using large quantities of scrap. The publication of the British Non-Ferrous Metal Statistics show that almost half of the U.K. production of around 200,000 tons/yr. of fire refined copper is scrap and the other half being imported blister copper. This situation does not hold for U.S.A. and other countries. It appears that the bulk of the 100,000 tons/yr. of scrap has been from cable-manufacturing operations or from old cable and wire installations. In fire refining, there are limited possibilities of eliminating impurities and, in a general way, the readiness with which elements are eliminated is related to the heats of formation of the metallic oxides but is dependent also on the extent of the solubility of the oxides in the metal. The recently published researches of B.N.F.M.R.A. throw much light on the subject of the elimination of tin and lead from copper in fire refining.

The operations of smelting into rough copper, casting into anodes, followed by electrolytic refining or chemical solution methods are reserved for material which cannot be absorbed direct in the metallurgical industries. Solid mixed scrap such as iron brass and gun metal from demolition operations often short-circuits the blast-furnace melting and is passed direct to a reverberatory furnace where the main process is that of evolution of zinc, lead and tin as oxides in the gases.

There are two different methods of electrolysis, one being the refining of copper anodes of about 98·5 to 99% copper, and the other the refining of bronze anodes of 85 to 90% copper and 10 to 15% zinc, lead and tin. Statistics show that about 100,000 tons/yr. of cathode copper in U.S.A. is derived from secondary metal, and in this country the recent production has been some 20,000 tons/yr. Only a small quantity is electrolysed by the bronze anode process. An alternative process is that of the Chemicals Corporation.

The meeting was presided over by Dr. Hugh O'Neill, Professor of Metallurgy, Swansea University.

BOOKS

X-Ray Crystal Structure

By Dan McLachlan, Jr., Stanford Research Institute. xiii + 416 pp. McGraw-Hill Book Company, Inc. New York and London, 1957. 116*s*. 6*d*.

THIS is a specialist's book, and the purpose of the present text is to furnish a common source in which the student may find condensed the teachings of the pioneers in crystallography. The book may also serve as a university text in a two-quarter course in structure analysis. The first four chapters pertain to crystallography, preparatory to the last five chapters which are on structure. It also forms an introduction to very wide fields of recent research, modern lines of approach and present ways of thought concerning X-ray crystal structure. Prof. McLachlan has succeeded in producing a most stimulating and inspiring account of this most important development in physics as applied to problems of the real physical world. The subject is presented in a most attractive and charming manner, and the individual chapters are enriched with excellent illustrations which are of very considerable interest, and which often throw a great deal of light on the historical development of the subject. The book is notable for the wide ground covered and the lively discussion of certain fundamental matters.

The list of achievements in the successful applications of X-rays in the study of the structure of matter is a long one; however, the contributions to the fields of textiles, fibres, drugs, metals, minerals, foods and living tissues are beyond the scope of this text. While the book is largely devoted to the use of X-rays in structure determination, the first chapter discusses the general properties of crystals, emphasizing atomic positions, Miller indices, orientation within the crystal, interplanar spacings and stereographic projections. The investigator of any new crystal should first look at the crystal under the microscope before commencing the X-ray investigation. It must be realized that X-rays do not give evidence of static symmetry operators. This chapter shows the point group to which a particular crystal belongs and how it can be determined from the external symmetry using optical methods.

The next three chapters are devoted to point and space groups, the special applications of X-rays and the determination of space groups. The interest in glides in X-ray crystallography is because operations cause a halving of certain classes of interplanar spacings, and this halving results in systematic extinctions in the X-ray diffraction patterns, from which the investigator can deduce the space group to which any particular crystal belongs. X-rays are extremely sensitive to glides and only subtly sensitive to symmetry. Originally, Laue pictures exclusively were used for determining the space groups, more recently, however, because of their greater convenience, monochromatic beams have been adopted along with rotation of the crystal. Professor Bernal contributed extensively in the early days to the interpretation of rotation pictures. Although the Braggs made use of ionization chambers almost from the very beginning of X-ray diffraction in 1912, the bulk of the work in England, Europe and U.S.A. in recent years has been conducted using photographic methods. However, when the North American Phillips Company commercialized the Geiger-tube spectrometers for the recording and measurement of powder diffraction data, several investigators conducted incidental experiments to explore the possibility of extending the use of the apparatus to single crystals.

The primary aim of the first part of the fifth chapter is to give a satisfactory explanation of the two most commonly used equations for the scattering of X-rays from single crystals. Throughout this chapter, the wave concept is based on the principles laid down by the Maxwell equations, but the mathematical treatment is reduced to its simplest essentials. The final chapter is devoted to 'examples of structures which have been determined,' and illustrates the determination of the locations of the atoms within the unit cell of a particular crystal. Robertson has developed a microdensitometer for placing the X-ray film under the microscope and then counting the grains in the emulsion, and some commercial automatic microdensitometers have been marketed. Titanium nitride is chosen as a first illustration because its structure is simple and represents a problem having no parameters. One of the chief objectives of structure analyses is the accurate determination of the distances between atoms and their neighbours and the angles which the bonds between atom pairs make with adjacent pairs. The structure of trimethylamine sulphur trioxide is an example of one in which groups of atoms rotate while the materials are in the solid state.

The volume concludes with an appendix dealing with special recording techniques. This volume will doubtless come to be one of the standard textbooks on this important subject.

E. LEWIS

La Diffusion dans les Metaux

Edited by J. D. Fast, H. G. Van Bueren and J. Philibert. 130 pp., 86 figures. Philips Technical Library, 1957 (Eindhoven). Distributed by the Cleaver-Hume Press Ltd., London. 37*s*. 6*d*.

THE eleven papers in this book formed the basis of a symposium held in Eindhoven during September, 1956. Of the 31 people present, 14 were from Holland, nine from France, five from Belgium and one each from Great Britain, Germany and the Saar. The papers are all in French. The list of participants shows the presence of representatives of most of the research laboratories in France, Belgium and Holland which are actively interested in diffusion in metals.

Whilst the scope of the symposium is wide, the papers can be divided into groups. An introduction by A. D. Le Claire discusses, briefly, thermodynamic and atomic treatments of the diffusion process with particular application to the variation of diffusion rate with composition. It includes reference to the relationship between diffusion and lattice defects, the Kirkendall effect and grain boundary diffusion; which subjects are dealt with in the symposium. It concludes with a discussion of techniques for measuring diffusion rates together with an indication of the factors which are measurable. A very brief paper by K. Compaan and Y. Haven correlates atomic movements for diffusion of silver in the AgCl lattice; this problem arises when tracer elements are used for diffusion studies.

Grain boundary diffusion studies seem only recently to have begun to receive the more concentrated effort which they warrant. Perhaps this is necessarily associated with the now popular use of tracer techniques. P. Lacombe reviews the subject admirably and includes a discussion of the techniques and dependence of the results on the mis-match between the lattices of the grains on either side of the boundary. This is a valuable contribution to the book and, incidentally, is the longest paper.

A specific application to boundary self-diffusion in alpha iron is reported by C. Leymonie and P. Lacombe.

Four papers are devoted to Kirkendall effect and related studies. T. Heumann discusses particularly the systems Au-Ag (with complete miscibility) and Cu-Sb (with the formation of intermetallic compounds). He concludes with a brief discussion on electrolytic transport, considered as a problem in diffusion. The Castaing technique (micro-scale X-ray fluorescence analysis) has been applied to the systems U-Zr and Fe-Cu by J. Philibert and by Y. Adda and J. Philibert. The technique can analyse an area of about 2μ diameter. Its value is clear and indications of the sensitivity of the technique are given in the diagrams. A. Bolk and T. J. Tiedema present a short experimental paper on the Kirkendall effect in the system Au-Pt.

Interstitial diffusion is dealt with in two papers. J. L. Meijering discusses H, C, N and O in various metals, mostly with reference to internal friction techniques. The effects of alloying elements on interstitial diffusion is also considered, for example, the system Fe-Mn-N. Van Wieringen illustrates the use of the mass spectrometer for the investigation of flow of helium through silicon and germanium.

The final paper by C. W. Berghout considers the effect of elastic stresses on diffusion of vacancies in copper. The application of a tensile stress introduces anisotropy into the measured diffusion rates.

The book will be of value mainly to those whose interests be within the several narrow fields discussed; under this condition the contents are very good. The book is well produced, with good diagrams and a useful index. The editors and the Philips organization are to be congratulated on their effort. It is appropriate perhaps to emphasize this useful contribution from the Philips Laboratories. Other laboratories whose interest in fundamental research work should be as great might make similar contributions to scientific progress.

G. M. LEAK

The Solidification of Castings

By R. W. Ruddle. 2nd Edition. Institute of Metals, London, 1957. 406 pp., 306 refs. 42*s*.

THIS second edition is a greatly enlarged and completely revised version, being almost four times the size of the first edition in 1950. The author has succeeded well in his aim of giving a comprehensive and critical survey of the voluminous literature concerned with the subject in hand. The text may, broadly speaking, be divided into three sections. The first, comprising two chapters, deals with the experimental methods used in this particular field of research, and with the mechanism which governs the freezing of all types of metals and alloys.

Fundamental aspects are covered in four chapters, the first of which is concerned with mathematical treatments, and the author, realizing that many readers will not wish to study these, has carefully arranged the text so that omission of these particular pages does not impede the continuity. Heat extraction, both by sand and chill moulds, and solidification rates are discussed in detail.

The closing chapter is concerned with the application of the methods reviewed to the production of sound castings, and it is this section, together with the opening chapters, which is likely to be of greatest value to the practical foundryman. Continuous casting receives individual treatment, this particular chapter being subdivided into sections corresponding broadly with the main chapters dealing with static ingots. Two appendices give thermal data on mould materials and metals and mathematical information required for calculation.

Throughout the work the author has taken care to cover as wide a range of materials as possible, so that the text is of like value to the ferrous and non-ferrous founder. Moreover, the layout is such that, together with the comprehensive index, easy reference to any particular topic is ensured. The style, as is perhaps inevitable in a review of literature, becomes a little monotonous in parts due to the frequent repetition of the sane names—for instance, one trio of authors is specifically mentioned ten times in two consecutive pages. On the whole, the book well deserves a place in the library of anyone concerned with the melting and casting of metals.

G. HOYLE

Corrosion and Wear Handbook for Water-cooled Reactors

Edited by D. J. Depaul, with 54 contributing authors. 293 pp., with 152 illustrations and 50 tables. McGraw-Hill Book Company, Inc.

WHEN the United States Navy and Atomic Energy Commission undertook a programme for the construction of the nuclear energy powered submarine *Nautilus*, a large amount of project work was put out to contract and sub-contract. Thus the various organizations participating in the project amassed a large amount of information, and it is the purpose of this handbook to collect and correlate the information concerned with corrosion and wear. It is therefore mainly concerned with the materials of construction of nuclear reactors, an in particular, with stainless steel, although details of other materials are given.

To achieve this aim the work is conveniently divided into three sections: Part A, Fundamental and General Principles; Part B, Procedures and Data; and Part C, Special Studies.

Part A comprises four chapters, two of which are excellent reviews of the fundamental aspects of corrosion, and friction and wear. It is interesting to note the wide range and international nature of the references used in compiling these reviews. Chapter 4 deals with water technology and the opening sentence qualifies the chapter thus: ' The chemistry of the corroding medium ' (in this case water) ' is of obvious significance to corrosion and wear problems.' Nuclear radiation of fast neutrons dissociates water into free radicals, whereas γ radiations enhance recombination. The effect of this process and of radiation syntheses on the susceptibility to corrosion are discussed. A new term ' crud,' meaning ' the insoluble corrosion products formed in the primary coolant of water-cooled reactors ' is introduced.

Part B comprises four chapters, two of which detail the apparatus used in corrosion tests and the general method of approaching the problems. Then follows the tabulation of the data—in all, some 34 pages giving details of the corrosion and wear tests on metals varying from carbon steels to cermets. Based on the results given in Chapter 7, the relative importance of such variables as composition, temperature, time, water velocity, gases, stress, heat treatment, etc., are discussed.

Part C deals with special types of corrosion and an account of the results involving wear. In particular, the chapters on crevice and stress corrosion are worthy of mention—the latter, the work of some 22 contributors, contains much useful information, many micro-photographs and quotes 53 references. On the other hand, the subject of intergranular corrosion is covered in a mere four pages—and this the work of eight contributors.

NEWS

Heat-treatment Equipment for Nottingham

A RECENTLY opened extension to the Raleigh Industries Ltd. factory at Lenton, Nottingham, has been equipped with many modern devices. The equipment, ordered from Imperial Chemical Industries Ltd., includes 12 'Cassel' heat-treatment furnaces and one metal degreasing plant.

Six of the furnaces are each 42 ft. long and are conveyorized to handle work automatically through pre-heat, carburizing, quench and wash. Two of the remaining furnaces are also entirely automatic, and are to be employed for the refining treatment after case-hardening of small parts, such as bearings and three-speed gear components, which can be transferred from one container to another. The four remaining plants are for deeper carburizing on a batch system, the work being handled by overhead runway.

The continuous trichloroethylene degreasing plant, with the exception of some minor modifications and a 25% increase in capacity, is similar in design to an existing plant supplied by I.C.I. some years ago. It is designed to degrease 200 tons of cycle parts during a working week of 100 h., and will be used to remove the lubricant with which the parts become contaminated during the several stages of pressing. Many parts are degreased more than once, initially to permit inter-stage annealing, and then in preparation for subsequent processing. Rotating baskets are fixed to a double-chain conveyor, and the work is 'tumbled' during passage through trichloroethylene liquor and vapour compartments to ensure efficient degreasing and to prevent the loss of solvent trapped in 'cupped' or close-lying parts.

As a further aid to economical and safe operation, the plant is fitted with an activated carbon recovery unit to recover solvent from the air exhausted at the plant inlet and outlet hoods.

Metals in Hungary

Hungary has begun the manufacture of machine parts from iron powder at the Budaörs Metal Works, near Budapest. Bearing caps, flywheels for toy cars, self-lubricating bearing brushes, bearings for washing machines and parts for textile machines are being made, reports the newspaper *Népszabadság*. Tools 'filled' with hard metal are also being made, such as presses, lathe heads, drill heads and sand drills. Life span and wear is estimated at between 10 to 100 times greater than that of steel tools. Hard metal splinters are being embedded in the binding material of the metal, producing a hardness approaching that of diamond tools, it is claimed. Crown bores for metal and oil drilling can be made by this method. Now that Hungary has begun home production of these tools, imports have stopped and exports sent to Yugoslavia, Egypt, Turkey, China, Brazil, Poland and Mongolia.

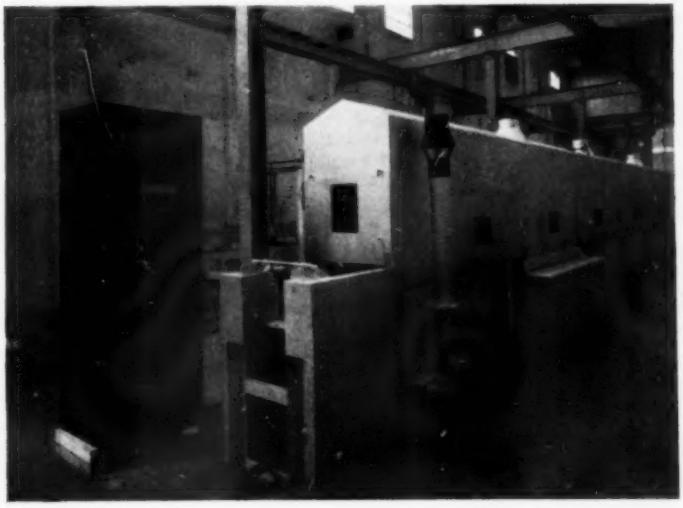
Iron scrap is ground down and the granules separated according to size and pressed into shape. They are then heat-treated, processed and pressed.

Hungarian Foundry Development Plan

A £1-million development plan at the Csepel Metal Works, Budapest, will save Hungary imports totalling $500,000 a year when completed. Under the current three-year plan, a modern vacuum furnace and sheet-metal rolling plant will be built. Special tempering equipment will be installed which will be suitable 'for improving the electric properties of metal,' reports the newspaper *Népszabadság*.

Kent-Continental Expansion

Kent Continental Societé Anonyme, the Belgian subsidiary of George Kent Ltd., Luton, Beds., announces that it has moved into larger premises at 27 rue Paul-Emile Janson, Brussels. The telephone number, Brussels 38.31.84, remains unchanged, but a further line has been added which carries the number 37.78.15. The telegraphic address is now 'Kentinental Brussels.'



One of the gas-fired, totally enclosed automatic Cassel salt-bath furnaces viewed from the loading end before installation

Corrosion products, both soluble and insoluble, may cause fouling and high radioactivity levels in primary loops of water-cooled nuclear power units, and a short chapter is devoted to the accumulation and removal of such products (crud). Chapter 13 deals with considerations of wear and contains an interesting section on the practical considerations in choosing materials. The concluding chapter is a treatise on cleanliness and a photograph showing the debris collected from a coolant filter after construction emphasizes the need for such a chapter.

A glossary of terms completes a book in which a great deal of information on corrosion and wear from many sources has been collected together and presented in a compact and readable form.

G. R. MORTON

Metallurgical Aspects of the Control of Quality in Non-Ferrous Castings

Institute of Metals Monograph and Report Series No. 22. Institute of Metals. London, 1957. 35*s*.

THIS monograph includes the text of eight papers (Nos. 1744-6, 1749-52 and 1754) given at the Symposium held during the annual general meeting of the Institute of Metals in London in May, 1957, together with the discussions on these papers. The theme of all these papers is the control of quality, by the use of test methods and test equipment, from the metallurgical point of view in the casting of non-ferrous metals. Each paper throws light on some facet of this important subject, both in a general and also in a particular way, with 20 plates and some 120 figures and tables to illustrate the text.

Ruddle and Cibula, in an excellent paper, deal with the metallurgical reasons for defects in castings and with the scientific basis of methods to avoid these defects, under the main headings of: (*a*) Flow of liquid metal through gates and into mould; (*b*) freezing of castings: rate, mechanism and effect on porosity and on hot tears and segregation; and (*c*) control of melt quality: gas content, grain refinement, non-metallic inclusions and test-bar design. The discussion on this paper dealt, *inter alia*, with the phenomenon of heterogeneous nucleation, of which Cibula is such a strong exponent.

Martin in his paper on 'statistical methods of quality control' seeks to bridge the gap between foundry practice and standard textbooks on this subject and to show that statistical methods can play a useful part in the correct interpretation of information provided by inspection records, to which they are supplementary and not eliminatory. Production data can thus be sifted and systems of control be based thereon, once the causes of variations and the probabilities of their re-occurrence have been statistically evaluated. In his reply to discussion, the author laid emphasis on the first concern of all founders, namely, to sell castings and not test-bars.

Carless in his paper deals specifically with the more important aluminium alloy castings in common use, strictly from the metallurgical angle, excluding dimensional accuracy, for instance. Working procedures, metal treatments, maintenance of metal quality and methods of assessing soundness and composition are described in detail. In his reply to questions, Carless mentioned the beneficial effect of additions of grain refiners in improving the fluidity of certain aluminium-base alloys with 5% copper, 1 to 1·6% nickel, etc.

French's paper deals exhaustively with copper-base alloy castings, as included in B.S. Schedule 1400, produced mainly as sand castings. From the discussion it appears that the presence of larger amounts of sulphur, due to the use of fuel oils with higher sulphur contents, is causing trouble in these alloys, particularly in gun-metal.

Emley and Fisher deal with 'magnesium-base alloy castings, sand cast or gravity die-cast.' Methods are described for examining the various serious possible defects and for the application of the appropriate remedy.

The subject of Wood and Gregg's paper is the production of 'nickel alloy sand castings' to meet the exacting requirements of highly corrosive and high temperature applications. Emphasis is laid on control factors of special importance to these alloys, which must be perfectly homogeneous and free from undesirable components to stand up to the above-mentioned condition. Oxygen-lancing is described as it gives a high level of mechanical properties and improved weldability from scrap-metal charges.

Pressure die-castings, primarily in aluminium alloys, are the subject of the paper by Sharp. The large number of inter-related variables is a feature of this process and the skill of the operator plays an essential part, even when correct regulation and control-setting of the machine have been established. Pressure casting is semi-automatic and special considerations have to be applied. The author regrets it is still impossible for him to find a substitute for messy, dirty graphite as a lubricant, in spite of many trials.

The final paper by Fry on 'non-destructive testing in the control of quality of non-ferrous castings' deals mainly with radiographic examination, interpretation of results and defects revealed. This is now the most important method as it gives more information on internal defects than any other method. Ultrasonic testing may eventually be developed for shaped castings, as it is already done for billet testing, and this would replace radiography to some extent owing to its increased speed and reduced cost.

This volume will be a very valuable addition, and an ornament, to the library of all who are concerned with foundry progress and the Institute of Metals is to be congratulated on this latest number in its invaluable series of Monographs and Reports.

R. W. ALLOTT

Essential Strength of Materials

By F. R. Lisarelli. McGraw-Hill Book Company, 1957. $4.75.

THE title of this book is somewhat misleading; it is essentially an elementary introduction to the design of beams and sections. Students in the early stages of technical college courses may find it useful, particularly as the subject is treated in a simple manner without complex mathematics. The provision of worked examples and the liberal use of drawings give the book a distinctly practical slant.

However, the brief description of the properties of structural materials is virtually valueless. The stress-strain curve of a medium carbon steel is inadequately explained, and is likely to leave the intelligent student with the impression that past the 'ultimate' the steel becomes softer. Equally, the diagrammatic representation of the stress-strain curves of steel, cast iron, aluminium and concrete, all on one graph, and all terminating at about the same strain, may prove more misleading than illuminating. One is left with the impression that a modicum of co-operation or consultation with his colleagues should have enabled the author to eliminate most of the blemishes of this little book.

P. FELTHAM

PEOPLE

Mr. M. F. Dowding has been appointed chief engineer of Davy & United Engineering Co. Ltd., of Sheffield, consequent upon the death of Mr. W. W. Franklin, technical director of the company; and **Mr. A. A. Thomas** has succeeded Mr. Dowding as the company's engineering sales manager.

Mr. Dowding, who is 39, is a Master of Arts, having obtained a Degree in Engineering at Cambridge University. After service in the 1939-45 war, he joined Davy-United as a graduate apprentice, and thus received his practical training with the company and gained experience in several of its departments before being appointed its engineering sales manager in 1950. He is a Member of the Institution of Mechanical Engineers.

Mr. Thomas also came to Davy-United from Cambridge University, where he had obtained a Degree of Master of Arts; and he served his apprenticeship in the works, later becoming Mr. Dowding's assistant. He is an Associate Member of the Institution of Mechanical Engineers.

A new post of deputy director has been created at the National Physical Laboratory, and **Dr. Edward Lee** has been appointed. Dr. Lee was educated at Consett Grammar School and graduated at Manchester University with First-Class Honours in Physics. After taking his M.Sc. at Manchester University and his Ph.D. at Cambridge University, he joined the Royal Naval Scientific Service in 1939 and was posted to the Admiralty Research Laboratory.

In 1946, Dr. Lee joined the Defence Research Policy Staff at the Ministry of Defence and from then until 1951 his work was mainly concerned with relating Service research programmes to the scientific effort available and Service requirements. He has been director of Operational Research at the Admiralty for the past three years. Dr. Lee takes up his new appointment on March 31.

The formation of Penco Research & Development Co. Ltd., with **Alexander Rubach** as managing director, has been announced by the Pena Group. The new company will co-ordinate engineering development and design within the group.

At the end of the war, while still in the Army, Mr. Rubach was seconded to the Ministry of Supply for guided weapons research. Subsequently, he was appointed assistant superintendent of experiments at the inception of the guided weapons trials range at Aberporth and a member of five technical panels of the Directorate of Guided Projectiles. Since 1946, Mr. Rubach's positions have included those of engineer-in-charge of the electronics laboratory of the engine research section of the Anglo-Iranian Oil Co. Ltd., and senior development engineer of A.P.T. Ltd., where he was responsible for the engineering design and manufacture of 'Mosaic' (Ministry of Supply automatic computer). Before joining Pena, he was a leading scientist and head of the experimental engineering department at the G.E.C. applied electronics laboratories, Stanmore.

Mr. David H. Bramley, M.I.Mech.E., head of the department of industrial administration at the College of Technology, Birmingham, has joined the board of Geo. Salter & Co. Ltd., the West Bromwich spring and spring balance manufacturers. He will continue to hold his college post. Mr. Bramley's industrial experience is practical as well as academic, for he served an apprenticeship in the motor vehicle industry, in which he remained for 17 years, undertaking production management responsibilities. Most of that period was spent with A.E.C. Ltd. and L. Gardner & Sons Ltd.

In 1947 he was chosen to set up the department of industrial administration at what is now the College of Technology, Birmingham. This department is now the largest centre of industrial administration teaching in the British Isles, and has a world-wide reputation. Mr. Bramley is a founder-member of the British Institute of Management and was a member of the special committee set up by the Minister of Labour in 1954 to make recommendations on supervisory management training in British industry. In 1951 he was a member of the Anglo-American Council on Productivity team which investigated the training of supervisors in the United States.

Recently, **Mr. David C. Nutting,** M.B.E., A.R.C.S., B.Sc., A.Inst.P., A.M.I.E.E., aged 39 years, joined the board of Solartron Industrial Controls Ltd., a member company of the Solartron Electronic Group. He is a full-time director responsible for processing contracts for the design and manufacture of electronic control systems for all manufacturing industries and for the sales of industrial control instruments.

Born in Sheffield in 1919, Mr. Nutting read physics under Prof. G. P. Thomson at the Royal College of

David C. Nutting

Science. On graduation he joined the R.A.F. as a volunteer, reaching the rank of squadron-leader. He was largely engaged on technical investigations of enemy equipment in the Middle East and, later, Europe. He was awarded the M.B.E. in 1945. Mr. Nutting joined the Bristol Instrument Co. Ltd., Weymouth, then gained further experience with Sunvic Controls Ltd., London, and was next appointed production manager with Thos. Hedley Ltd. at their Essex factory. In 1950 he was appointed project engineer and chief instrument engineer to E. B. Badger & Sons Ltd., the oil industry consultants.

A member of the Society of Instrument Technology, Mr. Nutting is chairman of its Control Section, a member of the Council, and the society's representative on the Standing British Conference on Automation and Computation. He is also a member of the Society of Chemical Industry. He is lecturer to post-graduate classes at the Battersea College of Advanced Technology and a governor of one of the pioneer comprehensive secondary schools in Battersea.

Wakefield-Dick Industrial Oils Ltd. announces the appointment of **J. W. MacMahon** as general manager of their Industrial Lubricants Division in succession to

U.K. Atomic Energy Authority

MR. W. R. J. COOK, deputy director of the Atomic Weapons Research Establishment, Aldermaston, has been made a full-time member of the Atomic Energy Authority. This new appointment makes it possible to progress towards certain alterations in the structure of the Authority. Three full-time members of the Authority have hitherto each had three types of responsibility. First, they have had executive control of one or more of the Authority's establishments. Second, they have been responsible for formulating policy on, and for broad oversight of, the subjects constituting their own special fields (research, production and engineering, and weapons). Third, they have had to join with their colleagues in considering and deciding jointly on the general policies to be pursued by the Authority. The purpose of the alterations is to free these members from their executive duties, and thus enable them to devote more time to their other responsibilities. Sir John Cockcroft, who has since the setting up of the Authority held the posts of member for scientific research and director of the Atomic Energy Research Establishment, Harwell, is succeeded in the latter post by Dr. B. F. J. Schonland (the present deputy director).

Mr. Cook will be responsible at board level for policy questions concerning the Authority's production factories and the engineering aspects of the Authority's work. Since Sir Leonard Owen was appointed managing director of the Industrial Group in September 1957, he has had executive charge of the establishments in that Group. Sir William Penney will continue to be member for weapons research and development and, pending the appointment of a new director of the Atomic Weapons Research Establishment, he will continue to hold that post also. The duties of Sir Donald Perrott, member for finance and administration, and of Mr. W. Strath, member for external relations and commercial policy, are unchanged.

National Physical Laboratory

During 1957 a comprehensive review of the organization and programmes of work of the National Physical Laboratory was carried out by a committee of the Research Council of the Department of Scientific and Industrial Research. As a result, the Research Council have now approved certain changes in organization which will become effective about the end of this month.

One of the most important is a reorganization of the work at present carried out in the Divisions of Electricity, Metrology and Physics and in the Test House. These four units will be replaced by three new Divisions to be called Standards, Applied Physics and Basic Physics.

Solartron Factory at Farnborough

Work has started on the first stage of Solartron's £1¼-million five-year expansion plan for increasing their production capacity at Tower Hill, Farnborough, Hants. The first section of the final building of 350,000 sq. ft. on the 15-acre site will be ready for occupation by August, 1958, and have an area of 50,000 sq. ft. This will house comprehensive manufacturing facilities in the fields of electronics, electro-mechanics, hydraulics, pneumatic and precision mechanical engineering.

The factory is being constructed by Taylor Woodrow Construction Ltd., using the Arcon Monitor roof of Taylor Woodrow (Building Exports) Ltd., and a new type of clad walling designed by Raglan Squire & Partners, Hobart Place, S.W.1, the architects, engineers and surveyors. The Monitor roof is flat with lighting introduced by means of upstanding Monitor frames glazed on each side. The roof is supported by columns spaced on a grid, carrying a superstructure of welded tubular lattice-framed beams. The construction for the external walls consists of special concrete blocks with an exposed aggregate surface.

The final factory of 350,000 sq. ft., including a four-storey administrative block, will be completed in four stages, the first of which will be completed and in production by August of this year. Initially the new works will employ 250 people, but, by stages, is expected, when the building is completed in approximately 1963, to give employment to over 2,000 persons.

EVENTS

March 19
Institute of Metals, Powder Metallurgy Joint Group. All-day informed discussion on 'developments in the practice of compacting and sintering.' Church House, Great Smith Street, London, S.W.1.

March 24
Institution of Production Engineers. The 1957 George Bray Memorial Lecture. 'The fabrication of plastics,' by Dr. V. E. Varsley. 6.30 p m at the University of Leeds. Admission by ticket only, from the secretary, Institution of Production Engineers, 10 Chesterfield Street, London, W.1.

March 24-27
EXHIBITION. Physical Society, at the Horticultural Hall, Westminster, London.

March 25-29
EXHIBITION. Electrical Engineers, at Earls Court, London.

March 26
Manchester Metallurgical Society. 'Some metallurgical aspects of nuclear power development,' by Dr. H. K. Hardy. 6.30 p m at the Central Library, Manchester.

March 31
Institution of Production Engineers. 'Ceramic cutting tools,' by G. R. Connor. 7.15 p m, at Manchester College of Science and Technology, Manchester.

April 3
Institute of Metals. London Section's annual general meeting followed by 'New protective coatings for metals' by W. E. Ballard. 6.30 p m at 17 Belgrave Square, London, S.W.1.

April 10
Leeds Metallurgical Society. 'Pressure die casting,' by G. Kelly. At West Yorkshire Foundries Ltd., Leeds.

April 14-19
EXHIBITION. Factory equipment, at Earls Court, London.

April 15-19
Institute of Metal Finishing. Annual Conference, at the Palace Hotel, Torquay.

April 16
Society of Chemical Industry, Corrosion Group. Annual general meeting. 6.30 p m, at 14 Belgrave Square, London, S.W.1.

April 16-25
EXHIBITION. Instruments, Electronics and Automation, at Olympia, London.

NEW PLANT

Refractory Protective Coatings

A new range of refractory protective coatings under the name of Coltrate R.P.C. was introduced recently by Coltrate Ltd., New Broad Street House, 35 New Broad Street, London, E.C.2.

Several types of Coltrate R.P.C. to deal with varying conditions are supplied in the form of a dry powder, which for use is mixed with water to a thick creamy paste and applied by brushing, spraying or trowelling. The coating thickness is from $\frac{1}{16}$ to $\frac{1}{8}$ in. After application, the furnace is fired and the temperature steadily increased up to the point where vitrification is reached.

The coating after fusing remains as a strong, continuous, monolithic lining that prevents cracking of the underlying refractories. It also penetrates and seals the pores of the refractories, and forms a barrier to gases and particles, and acts as a binder for loose particles and cracked portions.

The coating resists slagging and is not readily wetted by slag. The complete range covers the following temperature ranges: 'Loglaze' 1521—1,500 to 2,100° F.; 'Midglaze' 1823—1,800 to 2,300° F.; 'Higlaze' 2230—2,200 to 3,000° F.

A non-vitreous type—'Nonvit'—is also available, and this covers the complete temperature range from 50 to to 3,500° F. There is also a refractory mortar for bonding, patching and plugging, designed to be effective over a temperature range up to 3,000° F.

Rust-preventing Metal Coating for High-temperature Work

The introduction of Glostack, a new high-temperature coating specially designed for the protection from rust of steel chimney stacks, furnace doors and other steelwork subjected to high operational temperatures was announced recently by Corrosion Ltd., Southampton, Hants.

Glostack is a metal coating supplied in liquid form, and is applied by normal paint techniques. It is simple to use, as it does not need the addition of any hardener, accelerator or curing agent. The surface to be protected is suitably prepared, and then Glostack is brushed on to the cool surface. The coated article may be put back into service as soon as the coating is touch-dry, which takes about two hours.

The makers say that the coating will stand up to temperatures well over 800° F. for long periods, remaining stable and unharmed throughout the range. They claim that coating has outstandingly good resistance to weathering, and will successfully withstand attack by chemical fumes of the kinds normally found in the vicinity of gasworks, electricity power stations, chemical works, etc. The material is sold by weight and is supplied in 6-lb. and 12-lb. cans.

Improved Molytone Grease for Bearing Lubrication

Rocol Ltd., Swillington, near Leeds, introduced some time ago a combination of bentone grease and molybdenum disulphide, known as 'Molytone grease,' for bearing lubrication. The name now covers three greases recently developed and marketed as: Molytone 265 grease, 320 grease, and 380 grease. The replaced grease was of normal ball and roller bearing consistency—penetration 250 to 280. This was found to be on the borderline of suitability for application in some grease guns and too thick for many pressure systems and centralized greasing systems. There was also a demand for a grease suitable for miniature high-speed bearings and producing little drag in the very fine clearances of precision machinery. Although bentone greases can be used at temperatures near the flash point of the oil, continued use at high temperature tends to thicken the oil and thus stiffen the grease. These problems have been solved by the new range of greases.

2,500-ton Mechanical Forging Press

A 2,500-ton mechanical forging press with new features has been designed by Erie Foundry Co., Erie, Pennsylvania, U.S.A. Forging operators have pointed out the need for more working room at the press. In this press the front columns have been spread and the working area moved forward to give operators 8 in. more clearance for manipulating the work in and out of the die. Thus the operator can move closer to the die, use shorter tongs, and have greater visibility.

Overall press height is 11 ft. 3 in., a reduction of 3 ft. below that of conventional machines. This is accomplished by means of a Scotch yoke (sliding block) to transmit pressure from the eccentric shaft to the ram. The Scotch yoke also provides a larger bearing area, increases the rigidity of the press, and permits elimination of the pitman and ram pin. Circulating flood lubrication is provided for the main bearings, and the Scotch yoke is operated in an oil bath. Both main gear and pinion are herringbone design, of heat-treated alloy steel. This construction makes the gears stronger and quieter in operation, and carries the added value of reversibility for double life. The air-operated, two-plate clutch has been mounted on the main shaft, within the main gear. Bearings are mounted behind the clutch plate. The cover, piston and springs can be removed as a unit, making it possible to inspect the clutch lining with a minimum of effort. The brake is adjustable from the floor. The wide, cast-steel brake band, with bolted-in lining, is hinged and reversible for long wear.

A 2,500-ton model of this press has been set up at Pennsylvania for demonstration to potential users. Agents in the U.K. for Erie presses are Burton Griffiths & Co. Ltd., Kitts Green, Birmingham.

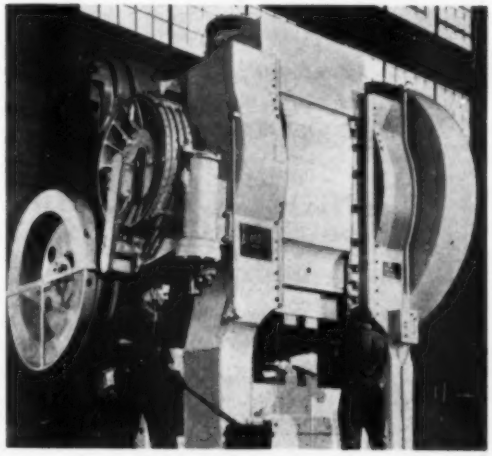


Fig. 1 *Erie forging press*

R. J. Turner, who has retired. Mr. MacMahon is also appointed to the board of directors of the company.

Mr. MacMahon, who is 49, began his career in 1925 as an office boy in the Wakefield industrial oils department but, about two years later, joined the export department where he remained up to the outbreak of war. Between 1936 and 1939 he travelled extensively on export business in Europe, the Middle East and West Africa. On leaving the forces he returned to the industrial oils department as a technical representative in the Midlands and was promoted sales manager in 1951, a position he retained later with Wakefield-Dick Industrial Oils Ltd.

J. J. Habershon & Sons Ltd. has appointed **Mr. P. Cook,** B.Sc., F.I.M., A.Inst.P., as research manager. Mr. Cook was formerly in the Mechanical Working Division of the Hoyle Street laboratories of BISRA.

The Deritend Stamping Co. Ltd. announces that **Col. J. W. Danielsen,** D.S.O., T.D., D.L., M.I.Mech.E., J.P., retired from the office of chairman at the end of last month. He is succeeded by **Mr. C. W. Perry,** who was deputy chairman. Col. Danielsen, who has been a director of the company for 56 years, will remain on the board.

Mr. J. H. Mayes, general sales manager of Northern Aluminium Co. Ltd., has been appointed to the board of directors. Mr. Mayes joined the company in 1934, in the technical section of Banbury works. Three years later he transferred to sales and he was head of the Sales Development Division from 1946 until 1952 when he took up the position of castings and forgings sales manager. In 1953 he was appointed export sales manager and in 1956 he became assistant general sales manager. He was appointed to his present position as head of the sales department in April, 1957.

Dr. A. D. Merriman, until recently Secretary of the Institution of Metallurgists, has been appointed by Edgar Allen & Co. Ltd., steel and tool manufacturers and engineers, of Sheffield, to advise that company on scientific projects.

Dr. Merriman is a native of Manchester and received his earlier education there. When he left the Manchester College of Technology he went first to Cambridge University, and then to the Universities of Lille and Durham, being engaged for a time at the last on educational research. In 1939 he was appointed to be a consultant of the Directorate of Scientific Research at the Ministry of Supply; and he became scientific adviser to the Commander-in-Chief, Middle East Forces, soon after the outbreak of the last war—an office in which he served until 1944. He returned to England for a brief period that year to take up membership of a special mission intended to link up with scientific workers in the Soviet Republic. Following that assignment he became superintendent of the Armaments Development Directorate of the Ministry of Supply. He was one of the scientists who participated in the post-war special missions that investigated industry in Germany; and later he was responsible for some of the examinations of flying-bomb and rocket launching sites which the Germans had established in France. In 1948, following a period in charge of Technical Intelligence, he became secretary of the Institution of Metallurgists—a position that he held until his retirement at the end of last year.

Dr. Merriman is the holder of the George Cross, an Officer of the Most Excellent Order of the British Empire, a Deputy-Lieutenant of the City of London, a Master of Arts, a Master of Education, a Doctor of Science, a Companion of the Institute of Mechanical Engineers and a Fellow of the Royal Society of Edinburgh. He is aged sixty-five.

With the late Mr. J. S. Bowden, Dr. Merriman was responsible for the 'Dictionary of Metallurgy,' which appeared in *Metal Treatment* in serial form and was concluded exactly a year ago. The complete work will shortly be published in book form by Macdonald & Evans Ltd., 8 John Street, London, W.C.1.

Mr. Peter M. Gavin has joined the staff of Paul Granby & Co. Ltd. as sales representative in the North Midlands, *i.e.* Yorkshire, Lancashire, Cheshire, Derbyshire, Lincolnshire, North Staffordshire, etc. Mr. Gavin was previously with Messrs. English Steel Corporation, from 1938 to 1957, at one time as manager of the Manchester drop-forging department and later of the steel foundry at Sheffield. He succeeds Mr. John Dodd as representative in the North Midlands.

No new appointment will be made for the Birmingham and Coventry areas, which districts will be handled personally by Mr. Paul Granby with the assistance of Mr. D. Charles-Edwards.

Elliott Bros. (London) Ltd. has announced that **Mr. George C. Fairbanks,** M.I.P.E., a deputy general manager of the company, has been appointed a director.

Mr. Fairbanks, who is 48, joined Elliott Bros. in 1930 as a tool-maker. In 1933 he became supervisor of the Admiralty Gyro Department and, by the end of the 1939-45 war, he was shops superintendent at the company's Lewisham factory. Immediately following the war Mr. Fairbanks was appointed production manager at Lewisham and subsequently assumed various senior executive positions including his appointment, two years ago, as a director of the Fisher Governor Co. Ltd. and Bristol's Instrument Co. Ltd., both Elliott subsidiaries.

Dr. B. R. Nijhawan, director, National Metallurgical Laboratory, Jamshedpur, India, has been given the award of 'Padma Shri' by the President of the Union Republic of India at the last Republic Day, January 26, 1958, in recognition of his distinguished services in the fields of science in India.

Conversion from Coal to Oil

Spear & Jackson Ltd., Sheffield, have recently carried through an extensive conversion programme and all previously coal-fired furnaces in rolling mill, forge and heat-treatment departments now use oil or gas as fuel.

The latest installation of a new oil-fired furnace in the sheet mill has been specially designed to give a controlled heat input with a temperature range of 750 to 1,300°C. for heating slabs and 'cheeses' (circular saw slabs), prior to rolling into sheets and subsequent processing into saws of all kinds. Spear & Jackson are believed to be the first to go into the application of oil-firing for this special purpose. Trials are expected to confirm both the economic and technical advantages of the method.

Atmosphere control coupled with automatic temperature regulation and fuel economy are achieved by the use of self-proportioning oil burners. Additional economies are secured by employing exhaust gases from high-temperature chambers on either side of the furnace, these hot gases being transferred to a central low-temperature chamber fitted with booster burners. It is interesting to note that the design of the furnace also permits its use for heat-treatment purposes. Overheating and wasteful use of fuel with its attendant smoke is prevented and guesswork in judging temperatures by eye is replaced by an auxiliary control panel, part of the installation which has been designed by Spear & Jackson in conjunction with the furnace builders, Messrs. Markham (Sheffield) Ltd.

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A refractory concrete for casting special shapes, lining furnace doors, chimneys, moulding baffles, cover blocks, burner blocks, destructor roofs, etc. Supplied dry. Maximum service temperature 1300°C.

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A high duty refractory concrete suitable for similar applications to Durax No. 2 but where higher temperature conditions operate. Supplied dry. Maximum service temperature 1500°C.

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A refractory concrete for casting linings and special shapes. Supplied dry. Maximum service temperature 1320°C. Slightly higher than Durax No. 2.

DURAX No. 12

A refractory concrete possessing a higher mechanical strength than any other in the Durax range with only a slight loss in refractoriness. Supplied dry. Maximum service temperature 1200°C.

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Similar properties to No. 2 but more finely ground to facilitate casting thinner sections. Supplied dry. Maximum service temperature 1300°C.

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A finely ground air setting cement for jointing all types of firebricks. Supplied dry. Maximum service temperature 1650°C.

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Similar cement to Durax No. 3 but for use at lower temperatures where very stong joints are required. Supplied dry. Maximum service temperature 1000°C.

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A finely ground jointing cement with a hydraulic set which is insoluble in water. Suitable for jointing bricks in water washed hoppers and chimneys. Will resist the action of dilute acid. Supplied dry. Maximum service temperature 1300°C.

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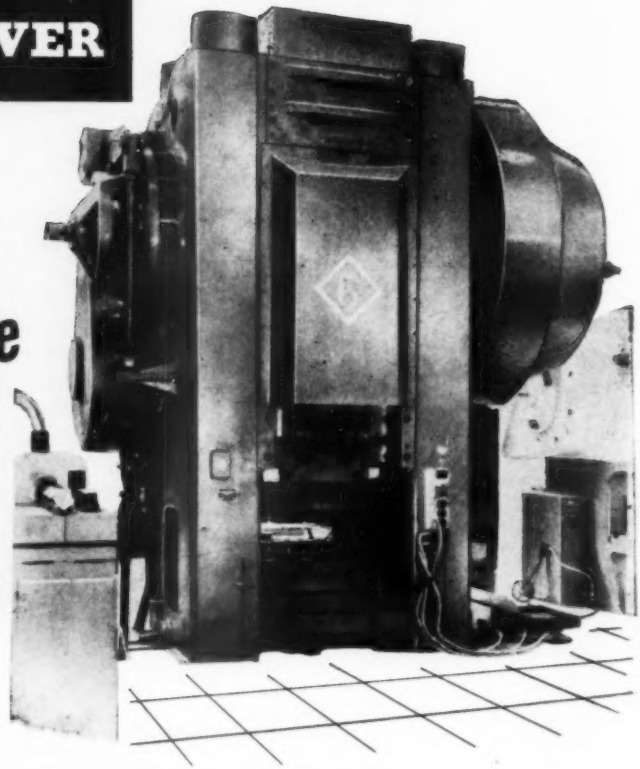

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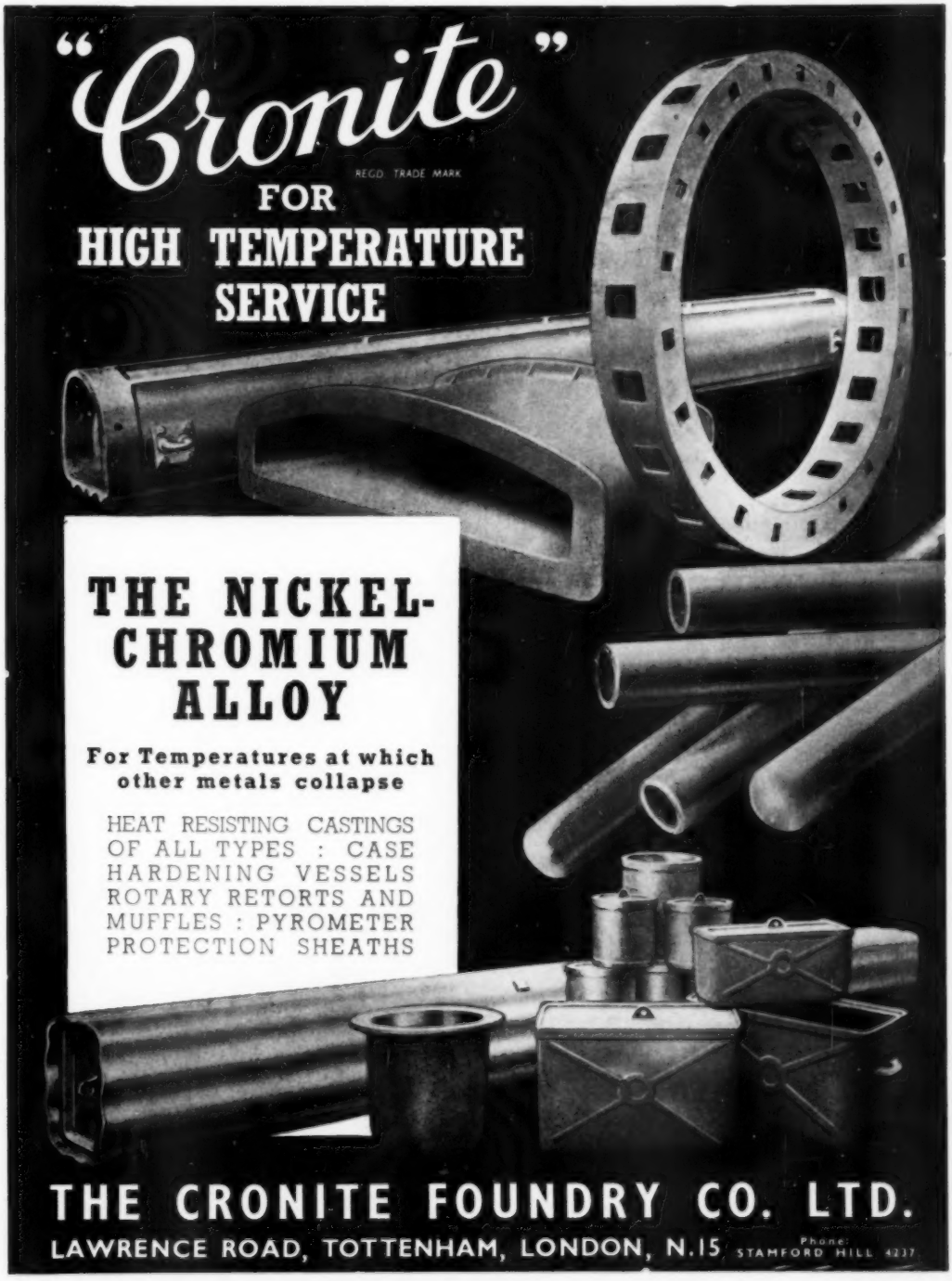
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